## APPENDIX F

## OCTOBER 1, 2002 INTERNAL CORRESPONDENCE EXPECTED WATER INFLOW RATES



## **Skyline Mines**

### **Internal Correspondence**

Date:

October 1, 2002

Subject:

**Expected Water Inflow Rates** 

From:

Doug Johnson, Chris Hansen

To:

Dan Meadors

Canyon Fuel Company, Skyline Mine ("Skyline") has encountered significant underground water inflows (1,000 gpm or more) in a number of underground locations over the past three-and-one-half years. These inflow locations are as shown on the attached map (Figure 1). The inflows are summarized in Table 1 below:

TABLE 1

				Initial	Present	Present
		Date Flow	Elevation	Inflow (gpm)	Inflow (gpm)	Pressure
No.	Location	Began	(FASL)			(psi)
Α	14L HG	Mar 1999	8140	1,600	800	N/A
В	16L HG	Dec 1999	7985	1,200	800	N/A
С	Diagonal Fault	Mar 2001	8150	1,000	300	40 psi
D	10 Left	Aug 2001	8040	6,200**	3200	80 psi
Е	East Sub, xc 5	Oct 2001	8135	1,000	400	60 psi
F	11L HG, xc 24	Feb 2002	8040	1,000	900	100 psi
G	11L HG, xc 40	Mar 2002	8020	1,000	1500 *	100 psi
Н	11L set up room	Mar 2002	8000	1,500	1300	100 psi
				Total	9200	·

<sup>\*</sup> Note: The fracture at xc 40 has now exposed from xc 40 to about xc 34 along the longwall face. The inflow has increased to a total of about 1,500 gpm.

This water is staged through pipes and sumps in the mine and discharged to Eccles Creek where it eventually flows into Scofield Reservoir in the Price River drainage.

Due to the volume and persistence of the inflows, Skyline has changed its mine plan and is now mining north to the Winter Quarters (North) Lease rather than west to the Flat Canyon Lease (unleased).

Near the end of September 2002, Skyline removed the pumps and electrical distribution system from the 10L area and began sealing as shown on the attached map, Figure 2. This will allow water to fill the 10L faces as well as much of the 9L gob as shown in Figure 2. Increased water depth in this area will put hydrostatic pressure against the fractures that bring water into the 10L faces and will decrease the inflow quantity. It is estimated that the inflow will reduce from the present 3,200 gpm to a new quantity of 2,490 gpm when the water has risen to an elevation of 8120 in about December 2002, and is drawn off through a dam shown on Figure 2 as Location X.

<sup>\*\*</sup> Corrected by Chris Hansen 3-01-04. Previously stated 6,500 gm.

[NOTE: For purposes of this evaluation, a simplistic approach which regards the relationship of the water inflow rate of a fracture to have a linear relationship with the head of the impounded water pushing against it was used. In actuality, the relationship is much more complex as the decrease of head available to overcome the static head of the impounded water will cause the cone of depression which has been created by draining the aquifer to decrease and allow reestablishment of a portion of the decreased pressure. For this evaluation a current "regional" static head of 8400 feet is used. The procedure is shown in Table 4 on page 3 of this report.]

Over the next 16 months, Skyline will finish mining in panels 11L, 12L "A" and 12L "B". That area will then be sealed (as shown in Figure 3) by March 2004. When water is allowed to rise to an elevation of about 8240 and is drawn off at Location Y as shown in Figure 3, it is expected that inflows will be as shown in Table 2 below:

TABLE 2

No.	Location	Expected March 2004 Inflow (gpm)		
Α	14L HG	492		
В	16L HG	308		
С	Diagonal Fault	192		
D	10 Left	1422		
E	East Sub, xc 5	242		
F	11L HG, xc 24	400		
G	11L HG, xc 40	632		
Н	11L HG, xc 62	520		
	Total	4208		

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This water will continue to be staged through the mine and into Eccles Creek.

In June 2004 it is projected that mining will be completed in Panel 6L "B". By the end of 2004 seals will be built to completely seal all areas south of the West Mains as shown in Figure 4. Water will be allowed to rise inside the sealed area to a maximum elevation of about 8290. If there is enough hydrostatic pressure in any of the inflows at C through H, then water may rise to that elevation and would be drawn off at Location Z as shown in Figure 3. However, it appears that there may not be enough pressure to overcome the head of the impounded water, and the pool may reach equilibrium without rising enough to flow out of the sealed area. At that time, it is expected that inflows will be as shown in Table 3 below:

TABLE 3

		Expected December 2004		
No.	Location	Inflow (gpm)		
Α	14L HG	338		
В	16L HG	212		
C	Diagonal Fault	132		
D	10 Left	978		
Е	East Sub, xc 5	166		
F	11L HG, xc 24	275		
G	11L HG, xc 40	434		
Н	11L HG, xc 62	358		
	Total	2893		

Expected Water Inflow Rates, October 1, 2002 Page 3

Over time, the cones of depression that have been created at each inflow location will level out and a new regional hydrostatic head equilibrium will be reached. It is expected that this new hydrostatic head will be lower than the pre-mining hydrostatic head as Skyline believes recharge to the aquifer is extremely slow or nonexistent. Once this new equilibrium is reached, it is possible that water may flow out of the sealed area at Location Z at a low rate. If, however, Skyline continues to operate well JC-1, it could continue to lower the hydrostatic head or keep it constant, preventing any water from flowing out at Location Z.

TABLE 4

			Current	•	Exp	ected Inflow	/S	
			Inflow	8400	8120	8240	8290	Static Head
No.	Location	Elevation	(gpm)		Oct-02	Mar-04	Dec-04	Date
A	14L HG	8140	800		800	492	338	
В	16L HG	7985	800		800	308	212	
C	Diagonal Fault	8150	300		300	192	132	
D	10 Left	8040	3200		2489	1422	978	
E	East Sub, xc 5	8135	400		400	242	166	_
F	11L HG, xc 24	8040	900		900	400	275	
G	11L HG, xc 40	8020	1500		1500	632	434	
H	11L set up room	8000	1300		1300	520	358	
	Total Flow	V .	9200		8489	4208	2893	₹.

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## **APPENDIX G**

## PETERSEN HYDROLOGIC REPORT

INVESTIGATION OF FAULT-RELATED GROUNDWATER
INFLOWS AT THE SKYLINE MINE
27 OCTOBER 2002

# **Investigation of Fault-related Groundwater Inflows at the Skyline Mine**

27 October 2002

Canyon Fuel Company, LLC Skyline Mine Helper, Utah

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## **Investigation of Fault-related Groundwater Inflows at the Skyline Mine**

27 October 2002

Canyon Fuel Company, LLC Skyline Mine Helper, Utah

Prepared by:

Erik C. Petersen, P.G.



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## Investigation of Fault-Related Groundwater Inflows At the Skyline Mine

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#### 1.0 Introduction

Canyon Fuel Company's Skyline Mine is located in the northern Wasatch Plateau coal district approximately three miles southwest of the town of Scofield, Utah. The mine was opened in December 1981. Through the end of 1998, relatively small amounts of groundwater were intercepted in the mine and mine discharge rates averaged approximately 350 gpm or less. However, starting in March 1999 and continuing to the present, significant fault-related groundwater inflows have been encountered in the Skyline Mine. As a result of the fault-related groundwater inflows, recent mine discharges in excess of 9,000 gpm have occurred.

The purpose of this investigation is to 1) characterize the nature and likely origins of the fault-related groundwater systems, and 2) determine the likely impacts of the fault inflows on the hydrologic balance. Including this introduction, this report contains the following sections

1

- Introduction
- Methods of Study
- Hydrostratigraphy and Geology
- Climate
- Presentation of Data
- Description of Groundwater Systems
- Likely Impacts to the Hydrologic Balance
- References Cited

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#### 2.0 Methods of Study

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The fault-related groundwater systems in the Skyline Mine area have been investigated by analyzing isotopic, geologic, and potentiometric data. Specific methods of investigation are described below.

#### Collection and Interpretation of Isotopic Data

Since 1993, Skyline Mine has collected stable isotopic, tritium, and carbon-14 data for radiocarbon dating. Much of this data was collected by Mayo and Associates, LC in conjunction with previous hydrologic investigations in the Skyline Mine and surrounding region. Additional data have been collected during 2001 and 2002 as part of this investigation.

Samples for tritium and for stable  $\delta^2H$  and  $\delta^{18}O$  analysis were collected in appropriate, tightly sealed HDPE and amber glass bottles, respectively. Samples for radiocarbon analysis on dissolved inorganic carbon (DIC) were collected in tightly sealed 5-gallon carboys. The DIC was prepared for analysis by precipitation in the laboratory using carbonate-free barium chloride under nitrogen gas to minimize the potential for atmospheric contamination. The pH of the samples was adjusted to pH 11 or greater at the time of precipitation using low-carbonate, regent grade sodium hydroxide.

Most stable isotopic  $\delta^2H$  and  $\delta^{18}O$  analyses were performed by Mountain Mass Spectrometry of Evergreen, Colorado. Other  $\delta^2H$  and  $\delta^{18}O$  analyses were performed by the BYU Stable Isotopic Laboratory of Provo, Utah. Tritium analyses were performed using electrolytic enrichment and low level counting methods by the Tritium Laboratory, University of Miami, Florida. Radiocarbon analyses used for radiometric dating were performed by Geochron Laboratories of Cambridge, Massachusetts. Groundwater mean residence times were determined using methods described by Pearson and Hanshaw (1970), Fontes (1980), and Mookes (1980).

The isotopic data collected from previous investigations and that collected for this investigation were compiled into an electronic database for analysis.

#### Existing Maps and Reports

Existing maps and hydrogeologic reports from the Skyline Mine area were obtained and reviewed.

#### Compilation of Existing Hydrologic Data

Solute and discharge data from springs, streams, and wells in the Skyline Mine area were obtained from Canyon Fuel and compiled into electronic format for analysis. Information on aquifer parameters, including hydraulic conductivity, specific yield, storage coefficients, and porosity were obtained from USGS reports and from published and unpublished sources.

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#### Data Analysis

Hydrologic data were analyzed using graphical and statistical methods. Solute chemical compositions were analyzed using Stiff (1951) diagrams and Piper plots. Groundwater mineral saturation indices were calculated using WATEQF (Plummer and others, 1976).

## 3.0 Hydrostratigraphy and Geology

The heterogeneous nature of the rock strata and bedrock fractures in the Skyline Mine area has a profound influence on the movement and storage of groundwater in the region. Consequently, a description of the geologic conditions in the region is presented here.

Five Cretaceous age bedrock formations crop out in the Skyline Mine area. These include, in descending order, the North Horn Formation, the Price River Formation, the Castlegate Sandstone, the Blackhawk Formation, and the Star Point Sandstone. The Mancos Shale, which intertongues with the Star Point Sandstone, does crop out east of the Skyline Mine area in Eccles Canyon and is present beneath the entire area. Additionally, the Cretaceous Price River Formation and the Cretaceous-Tertiary North Horn Formation are present in regions surrounding the Skyline Mine permit area. Each of these formations is described briefly below.

#### 3.1 North Horn Formation

The Upper Cretaceous-Tertiary age North Horn Formation is exposed on the highest ridge tops in the adjacent Flat Canyon and surrounding area. The formation consists primarily of shale with lesser amounts of interbedded sandstone, limestone, and conglomerate. Low permeability bentonitic mudstones dominate in the lower third of the formation. Isolated sandstone channels exist throughout the formation. In the Wasatch Plateau, where the North Horn Formation often forms the cap rock along ridges and plateaus, springs commonly discharge from hillsides near the ridge tops because of the inability of groundwater to migrate downward through the shales of the North Horn Formation.

#### 3.2 Price River Formation

The Price River Formation, which crops out along the ridges in the adjacent Flat Canyon and surrounding area, consists primarily of fluvial sandstones that are interbedded with shale and some conglomerate. Consequently, in outcrop the formation commonly forms alternating ledge and slope exposures. The lenticular, discontinuous nature of the fluvial sandstones, and the fact that the sandstones are encased in low permeability fine-grained material, prevents the transmission of water significant distances through the formation. Where the formation is exposed at the surface, shallow groundwater systems can form in the soil zone or in the uppermost fractured portion of the formation.

#### 3.3 Castlegate Sandstone

The Castlegate Sandstone is made up primarily of fine- to medium-grained fluvial sandstone. The formation was deposited in a braided stream environment, resulting in a series of lenticular, interpenetrating deposits. Thin interbeds of siltstone and claystone are common. The existence of mudstone drapes and the tightly cemented nature of the formation limit its ability to transmit groundwater. The Castlegate Sandstone is present in the northeast corner of the Skyline Mine permit area and in the western portions of the Winter Quarters area north of the existing permit area.

#### 3.4 Blackhawk Formation

The Blackhawk Formation consists of lenticular, discontinuous beds of sandstone, claystone, mudstone, shale, and coal. Because of the discontinuous nature of the rock strata, it is not possible to correlate individual rock layers over significant distances.

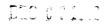
Sandstone paleochannels, which are sinusoidal fluvial sandstones encased in the surrounding low permeability, fine-grained rocks are present throughout the formation. Historically, sandstone channels encountered in the Skyline Mine sometimes contained water and other times were dry (Personal communication, Mark Bunnell, 2001).

Although the Blackhawk Formation is a poor transmitter of groundwater, nearly all springs in the Skyline Mine area occur on the Blackhawk Formation. This is because 1) most of the land surface in the permit area consists of Blackhawk Formation or Blackhawk derived sediments, 2) extensive soil and colluvial deposits are developed on the surface of the Blackhawk Formation which can accommodate the storage and transmission of groundwater, and 3) the interbedded low permeability shales and mudstones present in the formation prevent the downward migration of recharge water into the deeper subsurface and thus recharge water is forced to the surface as springs. No springs in the Skyline Mine permit or adjacent areas have been identified (with the exception of spring 17-2, discussed later) that are believed to have a significant deep bedrock flow component.

#### 3.5 Star Point Sandstone

The Star Point Sandstone consists of massive, fine- to medium-grained sandstone that is moderately well consolidated. Individual massive sandstone units are separated by partings of low-permeability siltstone or mudstone. The Storrs Tongue of the Star Point Sandstone interfingers with the basal portion of the overlying Blackhawk Formation in the Skyline Mine area. The Storrs Tongue of the Star Point Sandstone, which exists beneath the current Skyline Mine permit area, pinches out to the west in the Flat Canyon area. The Panther Tongue of the Star Point Sandstone underlies the Storrs Tongue in the existing permit area and the adjacent Flat Canyon area. The Panther Tongue is in most locations separated from the overlying Storrs Tongue be several tens of feet of relatively impermeable shaley deposits.

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#### 3.6 Structure

Numerous faults have been mapped in the current Skyline Mine permit area and the adjacent Flat Canyon area. The Skyline Mine area lies between two major north-south trending faults. The Pleasant Valley Fault is located in the Mud Creek area to the east and the Gooseberry Fault is located in the Gooseberry Creek area to the west. The Pleasant Valley Fault system juxtaposes rocks of the Star Point Sandstone against the shale, mudstone, and sandstone rocks of the Blackhawk Formation. The Gooseberry Creek Fault system juxtaposes rocks of the Star Point Sandstone against the predominantly shale bedrock of the North Horn Formation.

Several north- to northeast-trending faults with displacements up to a few tens of feet have been mapped in the existing Skyline Mine permit area and in the Flat Canyon area. Recent significant groundwater inflows at the Skyline Mine have been associated with these structures.

The rock strata in the southern portion of the Skyline Mine area are in a tensional stress regime (Personal communication, Mark Bunnell, 2002). This means that, in a general sense, the regional stresses are pulling the rocks apart. Consequently, rock fractures in the region (particularly the brittle sandstones of the Star Point Sandstone beneath the coal seams) can remain open (i.e. have a measurable aperture). Groundwater can be readily conveyed through these open fractures. The rock strata in the northern portion of the mine area do not appear to be in a tensional stress regime (Personal communication, Mark Bunnell, 2002). Regions north of the 6 Left through 12 Left longwall panels are separated from the southern portion of the mine by an east-west trending fault system that structurally isolate these two regions. A significant igneous dike in the same region likely also partitions groundwater systems in these two regions.

#### 4.0 Climate

Precipitation measured at the Skyline Mine surface facility between 1985 and 1995 ranged from 17.2 inches to 29.4 inches per year (Mayo and Associates, 1996). Monthly average temperatures at the mine site range from 8.0 to 74.4 °F (Canyon Fuel Company, 1999).

Climatic conditions in the Skyline Mine have varied substantially during the period of operation of the mine (1981 – present). This is illustrated in a plot of the Palmer Hydrologic Drought Index (PHDI) for Utah Region 5 (Figure 1). The PHDI is a monthly value generated by the National Climatic Data Center using a variety of hydrologic parameters that indicates wet and dry spells. The PHDI is calculated from several hydrologic parameters including precipitation, temperature, evapotranspiration, soil water recharge, soil water loss, and runoff. Consequently, it is a useful tool for evaluating the relationship between climate and groundwater and surface water discharge data. It is apparent in Figure 1 that the region experienced a prolonged period of moderate to extreme wetness beginning in 1997 and continuing through November 1999. Beginning in December 1999, the region rapidly transitioned to a period of moderate to severe drought that has continued to the present. It is

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primarily during this period of drought that the major fault-related groundwater inflows at the Skyline Mine have occurred.

#### 5.0 Presentation of Data

Water levels in selected monitoring wells in the Skyline Mine area are presented in Table 1. Water levels in selected monitoring wells are plotted in Figure 2a. Discharge rates from selected springs in the Skyline Mine area are plotted together with the Palmer Hydrologic Drought Index in Figure 2b.

Stable isotopic compositions of groundwater from springs and wells in the region and for inmine groundwaters in the Skyline Mine are presented in Table 2. As a part of Skyline Mine's ongoing hydrogeologic investigation, several isotopic tools have been utilized. These include radiocarbon dating of in-mine groundwaters, springs, and surface waters in the region, analysis of  $^3H$  (tritium) concentrations, and stable isotopic  $\delta^2H$  and  $\delta^{18}O$  analysis. A discussion of the practical application of these isotopic tools is presented in below. Isotopic laboratory reporting sheets are included in the appendix.

## $\delta^2 H$ and $\delta^{18} O$

The  $\delta^2 H$  and  $\delta^{18} O$  composition of precipitation is determined by the temperature at which nucleation of the water droplet occurs. Other effects, such as cloud rainout and orographic effects can also affect the  $\delta^2 H$  and  $\delta^{18} O$  composition of recharge water entering a groundwater system. The stable isotopic compositions of waters are usually analyzed relative to the Meteoric Water Line (MWL). Water that falls as rain and snow (meteoric water) in coastal regions plots near the MWL, which is defined as  $\delta^2 H = 8 \ \delta^{18} O + 10$ . Generally, recharge water that formed under warmer conditions will plot higher on the MWL than will water that formed under cooler conditions.

 $\delta^2 H$  and  $\delta^{18} O$  data can be very useful in evaluating the recharge and flow history of a groundwater system. Unlike the solute chemical composition, which is influenced by mineral dissolution and precipitation reactions, the  $\delta^2 H$  and  $\delta^{18} O$  composition is set at the time of recharge. Except for unusual conditions, such as geothermal heating above about 100 °C, the  $\delta^2 H$  and  $\delta^{18} O$  composition of a groundwater is not altered during residence in the groundwater system. In other words, the recharge and flow history of a groundwater can be evaluated independently of the solute content of the water using stable isotopic compositions.

The estimated error of the  $\delta^2 H$  and  $\delta^{18} O$  data used in this investigation as reported by the analytical laboratory is approximately 0.2 % for  $\delta^{18} O$  and 1.0 % for  $\delta^2 H$ .

#### Tritium

Tritium (<sup>3</sup>H), the radioactive isotope of hydrogen, has been used in groundwater investigations to differentiate between groundwaters that recharged prior to or after the advent of atmospheric thermonuclear weapons testing. Tritium, whose half-life is 12.43 years, forms naturally in the upper stratosphere by the interaction of <sup>14</sup>N with cosmic ray neutrons. Tritium is rapidly incorporated into water molecules and is removed from the atmosphere by precipitation.

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Investigation of Fault-Related Groundwater systems at the Skyline Mine

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Prior to the advent of atmospheric thermonuclear weapons testing in 1952, tritium activity in precipitation ranged from 4 to 25 tritium units (TU). One TU equals one <sup>3</sup>H atom per 10<sup>8</sup> hydrogen atoms. In mountainous areas, larger natural concentrations have been observed (Fontes, 1983). During the peak of atmospheric weapons testing, tritium levels in precipitation rose to more than 2,200 TU in some northern hemisphere locations (Fontes, 1983). As of 1987, the <sup>3</sup>H concentrations in rain water varied from 25 to 50 TU. Unpublished data of 1991, 1992, and 1997 snow and rain samples collected in the central Wasatch Range, Utah have <sup>3</sup>H concentrations ranging from about 5 to 20 TU or more (Mayo and Associates, 1999).

Tritium has been widely utilized in the hydrogeologic community using both qualitative and quantitative dating approaches (Clark and Fritz, 1997). However, in this and in previous hydrologic investigations at the Skyline Mine, tritium has been used only as a qualitative tool to determine whether groundwater has a component that recharged after the onset of aboveground thermonuclear weapons nuclear testing. No attempt to calculate an absolute "age" of groundwater has been attempted using tritium content. This is primarily because of uncertainties determining the tritium input level of the recharge water source(s).

The analytical error associated with each tritium analysis used in this investigation is indicated on the laboratory reporting sheet. Tritium analyses used in this investigation were analyzed using electrolytic enrichment and low-level counting, which allows for very low detection limits (0.1 TU). Analytical results are corrected by the laboratory for background cosmic intensity, gas pressures, and other parameters. The stated errors (eTU) are one standard deviation (1 sigma) including all conceivable contributions. Generally, the eTU for the low-tritium samples is approximately 0.1 TU.

#### Radiocarbon

As part of this investigation, radiocarbon dating of groundwaters and surface waters has been performed. Radiocarbon dating of dissolved inorganic carbon (DIC) in groundwater is very useful in discriminating the ancient groundwaters commonly encountered in Utah Coal mines from shallow, active-zone groundwaters and surface waters that are modern in origin. It is important to note that groundwater rarely travels via pure piston flow. Rather, groundwater arriving at a well, spring, or in-mine location is commonly a mixture of water molecules that recharged at different times and at different locations. Therefore, a radiocarbon "age" is best thought of as a mean residence time of all the water molecules in the sample.

Based on the known half-life of radiocarbon (approximately 5,570 years), it is possible to calculate the time since a groundwater became isolated from the surface. However, estimating the radiocarbon age of groundwaters is not as straightforward as estimating the age of dead organic matter. This is because groundwater acquires carbon from numerous sources, each of which must be accounted for in calculating a groundwater age. These sources may include "live" carbon from biogenic production of CO<sub>2</sub> in the soil zone, "dead"

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carbon from the dissolution of carbonate minerals in the soil zone, and the addition of both "live" and "dead" carbon by other processes. In the Wasatch Plateau region, groundwater commonly acquires its carbon through the following chemical reactions.

The partial pressure of CO<sub>2</sub> in the soil zone, which is largely derived through root-zone respiration greatly exceeds that of the atmosphere. The CO<sub>2</sub> reacts with water to produce carbonic acid according to:

$$CO_2 + H_2O = H_2CO_3$$

Carbonic acid dissociates to produce acid (H<sup>+</sup>) and bicarbonate according to:

$$H_2CO_3 = H^+ + HCO_3^-$$

In western coal mines, where carbonate rocks are pervasive, the acid produced from the above equation rapidly reacts with carbonate minerals which releases additional bicarbonate and calcium and/or magnesium ions according to:

$$CaCO_{3 \text{ (calcite)}} + H^{+} = Ca^{2+} + HCO_{3-}$$

Or

$$CaMg(CO_3)_{2 \text{ (dolomite)}} + 2H^+ = Ca^{2+} + Mg^{2+} + 2HCO_3^-$$

Thus, groundwater that follows this evolutionary pathway will acquire 50% of its carbon from soil-zone CO<sub>2</sub> and 50% of its carbon from the dissolution of carbonate minerals near the recharge zone. Because soil-zone CO<sub>2</sub> typically has a  $\delta^{13}$ C value between about -18 and -27 ‰, most groundwaters have a  $\delta^{13}$ C value in the range of approximately -9 to -13 ‰ (Mayo and Associates, 1999).

In this investigation, groundwater mean residence times have been calculated using models described by Pearson and Hanshaw (1970), Fontes (1980), and Mookes (1980).

Like tritium, radiocarbon can also be used to determine whether groundwater has a component of recent anthropogenic (human induced) carbon. Groundwaters with  $^{14}$ C contents significantly greater than about 50 percent modern carbon (pmC) have a component of carbon with an activity significantly greater than 100 pmC. Groundwater that acquires its carbon through the dissolution of carbonate minerals in the presence of soil-zone  $CO_2$  should have an  $A_0$  near 50 pmC (50% "live" soil-zone carbon with  $\approx$  100 pmC and 50% "dead" carbonate mineral carbon with  $\approx$  0 pmC). As a result of aboveground thermonuclear testing, the  $^{14}$ C activity of the atmosphere increased significantly above 100 pmC (with 100 pmC being based on the 1950 radiocarbon activity) (Clark and Fritz, 1997). Thus, it possible for a groundwater that recharge after about 1950 to have a  $^{14}$ C activity greater than 50 pmC. For this reason, groundwater age dating models that do not take this into account may

underestimate the actual residence time of the groundwater, sometimes even calculating a recharge date in the future.

Most radiocarbon analyses used in the calculation of radiometric ages were performed using conventional techniques. Some analyses were performed using accelerator mass spectrometry (AMS). The estimated analytical error for all radiocarbon samples used in this investigation are indicated on the laboratory reporting sheets. Generally, the radiocarbon laboratory results are within approximately +- 1 pmC.

#### 6.0 Description of Groundwater Systems

Groundwater systems in the Skyline Mine area are associated with one of two fundamental types of groundwater flow regime. These two regimes are described by a fairly simple conceptual model that includes "active" and "inactive" groundwater flow regimes (Mayo and Morris, 2000). The operation of these two regimes is fundamentally a consequence of the vertical and horizontal heterogeneity and discontinuity rock strata in the region. Active-zone groundwater systems are characterized as having good hydraulic communication with groundwater recharge sources and having active groundwater flow from recharge to discharge areas. Thus, they are dependent on annual recharge events and are affected by short-term climatic variability. Groundwaters in active-zone systems commonly have elevated tritium concentrations, which indicates recharge in the past 50 years. Inactive-zone groundwater systems are characterized by old groundwater, commonly from about 2,000 to 25,000 years in the Wasatch Plateau coal district. Inactive-zone groundwaters also exhibit a general lack of hydraulic communication with the ground surface or active recharge sources (Mayo and Morris, 2000). This condition is the result of the lack of recharge potential to deeper groundwater systems, either vertically or horizontally, because of 1) the abundance of low-permeability rocks in the rock sequence, and 2) the lenticular, discontinuous nature of the interbedded more permeable horizons that limits the extent of potential groundwater movement. Inactive-zone groundwater systems are not influenced by either annual recharge events or by short-term climatic variability.

With the exception of spring S17-2, all springs in the Skyline Mine and adjacent area discharge from active active-zone groundwater systems. Spring S17-2 is believed to have a significant component of groundwater that discharges from a fault associated with the Pleasant Valley Fault system. Groundwater discharge that provides baseflow to streams in the area is primarily from the active-zone. Springs in the Skyline Mine area exhibit pronounced seasonal variations in discharge rate (Figure 2b). Most of the springs also show a rapid response to the period of drought that began in 2000 and continues to the present as indicated by comparison to the PHDI (Figure 2b). The rapid response of most springs to the annual snowmelt event and the subsequent rapid declines in discharge rates to near dryness during the late summer and fall months suggests that the travel times from recharge locations to discharge locations are commonly less than one year.

Although the Blackhawk Formation is a poor transmitter of groundwater, nearly all springs in the existing Skyline Mine permit area occur on the Blackhawk Formation. This is because 1)

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there is a large surface exposure of the formation, 2) extensive soil and colluvial deposits are developed on the surface of the Blackhawk Formation which can accommodate the storage and transmission of groundwater, and 3) the interbedded low permeability shales and mudstones present in the formation prevent the downward migration of recharge water.

Most groundwater encountered within the Skyline Mine prior to 1999 originated from perched Blackhawk Formation inactive-zone groundwater systems. These groundwaters originated primarily from saturated sandstone paleochannels in the mine roof. The Blackhawk Formation mine inflows were commonly short-lived. After first being opened underground, the discharge rates from these systems commonly decreased rapidly and eventually these inflows diminished greatly or dried-up completely (Personal communication, Mark Bunnell, 2001). Seasonal or climatic discharge responses in these inflows were entirely absent. The old radiocarbon ages of these groundwaters and the lack of tritium (Table 2) indicates that these groundwaters were isolated from the surface and were part of the inactive-zone.

However, beginning in early 1999, significant groundwater inflows from the mine floor began to be encountered in fault systems intercepted by mine workings. While these groundwaters had very old radiocarbon ages and had very low tritium contents (near the laboratory detection limits), the inflows were significantly larger than those encountered previously in the mine and the groundwater inflow rates did not decline as rapidly as those from the mine roof.

The remainder of this report focuses on the description and characterization of these fault-related groundwater systems.

#### 6.1 Source of fault-related groundwaters

Based on many considerations, it is believed that the source of the groundwater in the fault-related groundwater systems is the Star Point Sandstone. The basis of this conclusion is discussed below.

#### Aquifer Temperature

Consideration of in-mine groundwater discharge temperatures strongly supports the conclusion that the fault-related inflows originate from the Star Point Sandstone. The average discharge temperature of the upwelling fault groundwater ranges from approximately 13.2 to 15.6 °C (Table 3), while groundwaters discharging from sandstone paleochannels in the mine roof near the fault inflows, such as 11 Left HG E1 XC62 (longwall set-up room) roof drip, which discharges at 8.9 °C, is more than 4 °C cooler. The water in the sandstone channel, with a radiocarbon age of 5,900 years and essentially no tritium (Table 2) and, prior to being intercepted by the mine workings, was not actively flowing, has equilibrated with the temperature of the surrounding rocks in the mine roof. Thus, based on an average geothermal gradient of approximately 23°C per kilometer depth (Written Communication, Dr. David S. Chapman, University of Utah, 2002), upwelling fault groundwater has a circulation depth on the general order of 187 to 291 meters (614 to 955 feet) below the mine workings (Table 4).

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These circulation depths are consistent with groundwater residing in the Star Point Sandstone beneath the coal seams. It is difficult to envision a mechanism whereby warm groundwater could migrate downward vertically through horizons of colder rock and colder groundwater above the coal seams and emerge as warm groundwater in the mine floor. It should be noted that groundwater from the 9 Left Horizontal Borehole discharges at an average temperature of approximately 9.7 °C, which is significantly cooler than other discharges from the Star Point Sandstone fault/fracture systems. Groundwater from the horizontal borehole flows through approximately 1,000 foot of uncased borehole surrounded by rock at the average mine temperature before discharging at the wellhead. During the groundwaters residence time in the borehole (the well was usually left shut in except immediately prior to sampling) the water temperature equilibrated with that of the surrounding rock.

#### 6.2 Potential for groundwater flow in adjacent geologic formations

The hydrologic properties of the geologic formations that exist above and below the mined coal seams are discussed below. Also discussed is the likelihood that each of the formations could be the source of the fault-related groundwater systems.

#### Mancos Shale

The Mancos Shale underlies the Star Point Sandstone in the region. The Mancos Shale is a marine shale deposit that is several thousand feet thick and is known regionally to contain abundant quantities of soluble minerals. The hydraulic conductivity of the formation is low. Published ranges of hydraulic conductivity for shale and unweathered marine clay range from approximately 10<sup>-7</sup> to 10<sup>-11</sup> cm/sec (Freeze and Cherry, 1979). Because of the very low permeability of the Mancos Shale, and the lack of competent rock strata in which fractures with aperture could form, large quantities of groundwater could not have migrated upward through this formation and entered the Skyline Mine. Additionally, groundwater that flows through the marine sediments of the Mancos Shale rapidly acquires elevated TDS concentrations due to the abundance of soluble minerals in the formation. The fault-related groundwater entering the Skyline Mine does not exhibit such elevated TDS concentrations. Thus, the fault-related groundwater system cannot be supported by groundwater systems in the Mancos Shale.

#### Blackhawk Formation

The Blackhawk Formation is exposed at the surface over most of the mined area at the Skyline Mine. The rocks of the Blackhawk Formation in the permit area consist of lenticular, discontinuous beds of sandstone, siltstone, claystone, and shale. The sandstone layers exist primarily as sandstone paleochannels. Well drilling reports and laboratory analysis of samples indicate that the claystone layers contain swelling clays that plastically deform when fractured. Chempet Research Corporation (1989) found that the claystone layers contained up to 58% low permeability montmorillonite clay.

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Published ranges of hydraulic conductivity for clay range from 10<sup>-6</sup> to 10<sup>-9</sup> cm/sec (Fetter, 1988). Lines (1985) analyzed cores taken from well (D-17-6)27bda-1 in the Trail Mountain area and found the hydraulic conductivities of the shales and siltstones to be very low (i.e. 10<sup>-11</sup> to 10<sup>-12</sup> cm/sec). One shale sample was found to be effectively impermeable even when a hydraulic pressure of 5,000 psi was applied.

The sandstone horizons in the Blackhawk Formation locally consist of aquifer-quality rock, with hydraulic conductivities locally perhaps on the order of 10<sup>-4</sup> cm/sec (Freeze and Cherry, 1979). The specific yield of sandstones typical of the paleochannel deposits in the Blackhawk Formation range from approximately 21 to 32%, averaging from 10 to 15% (Fetter, 1988). However, the potential for vertical or lateral migration of groundwater through these sandstone bodies is minimal. This is because the lenticular sandstone bodies pinch out laterally and are encased vertically and horizontally by the low permeability claystones, shales, and siltstones of the Blackhawk Formation. This situation can be likened to fluid flow through Swiss cheese. Although there are portions of the formation that are capable of transmitting water, because these portions (i.e. sandstones) are not interconnected with each other or with overlying recharge areas, the overall potential for vertical or horizontal groundwater flow through the formation is very limited. That this is the case is evidenced by the very old groundwater encountered in the Skyline Mine as well as other coal mines in the region. There is also a lack of seasonal or climatic response in discharge rates of in-mine groundwater inflows that would indicate hydraulic communication with overlying recharge sources. For these reasons, the Blackhawk Formation is not believed to be a potential source for the groundwater discharging from the fault-related groundwater systems at the Skyline Mine. For the same reasons, the downward migration of surface water through the Blackhawk Formation to the mine workings is not considered a reasonably likely scenario.

#### Star Point Sandstone

The Star Point Sandstone beneath the coal seams is believed to be the source of the fault-related groundwater that has entered the Skyline Mine. Although the Star Point Sandstone in most locations is a poor water producing formation, in some locations in the Wasatch Plateau, such as in the Skyline Mine permit area, the hydraulic conductivity of the formation has been locally enhanced by fracturing. In these areas, the Star Point Sandstone is a dual porosity system. Groundwater flow through the sandstone pore spaces is relatively slow, while groundwater flow through fracture systems can be significantly more rapid. Groundwater storage occurs in the pore spaces of the sandstone, while some groundwater storage also occurs in the voids of the fracture network.

Slug testing of unfractured Star Point Sandstone in the nearby Crandall Canyon area indicates a hydraulic conductivity ranging from approximately 1.3 x 10<sup>-6</sup> to 2.3 x 10<sup>-6</sup> cm/sec (Mayo and Associates, 1997). Hydraulic conductivity of the Star Point Sandstone measured in the Gentry Mountain area ranges from approximately 2.8 x 10<sup>-7</sup>

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<sup>6</sup> to 2.4 x 10<sup>-4</sup> cm/sec (EarthFax Engineering, 1992). The hydraulic conductivity of the Star Point Sandstone near the Straight Canyon Syncline in the Trail Mountain area (which is likely somewhat fractured locally) ranges from approximately 1.5 x 10<sup>-5</sup> to 1.3 x10<sup>-4</sup> cm/sec. At a single well in the Trail Mountain area that is known to intercept fractures in the Star Point Sandstone (CCCW-1S), a hydraulic conductivity of 2.7 x10<sup>-3</sup> cm/sec was measured (Semborski, 1994; Bills, 2000). The reported matrix porosity of the Star Point Sandstone ranges from 3% to 25.4% with an average of 15.5% (Bills, 2000). Storage coefficients of confined groundwater in the Star Point Sandstone measured at TM-3 range from  $2.3 \times 10^{-4}$  to  $7.8 \times 10^{-4}$  (Bills, 2000).

#### 6.3 Nature of groundwater flow

In portions of the Skyline Mine where the Star Point Sandstone is under a tensional stress regime and fractures can remain open (i.e., have a measurable aperture) appreciable groundwater flow through the formation can occur.

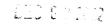
Water levels in monitoring wells in the region surrounding the mine workings have shown rapid responses to perturbations in the fault-related groundwater system resulting from inmine groundwater inflows and changes in the pumping regime at well JC-1. These responses are likely the result of hydraulic communication (pressure responses) through fracture systems in the Star Point Sandstone and are not related to the matrix permeability of the formation. Groundwater in Star Point Sandstone fracture systems can be transmitted rapidly when the fracture systems are opened underground. This is evidenced by the near instantaneous large inflow rates that commonly occur when significant water-bearing fracture systems are first intercepted by coal mining. The initial surge of groundwater that enters the mine workings when a fracture system is first opened must be derived from storage in the open fracture system, because the hydraulic conductivity of the sandstone matrix is not sufficient to support such large, instantaneous discharges (> 1,000 gpm) in a localized area. However, as the fault-related inflows persist over longer periods of time, the groundwater that subsequently flows from the system is likely derived from slow discharge of groundwater from the Star Point Sandstone. Groundwater discharge from a porous media may be calculated according to Darcy's Law:

#### Q=KIA

Where K = hydraulic conductivity, I = hydraulic gradient, and A=cross-sectional area. It is apparent from Darcy's Law that for a constant discharge (Q), there is a direct linear relationship between hydraulic conductivity and cross-sectional area. Thus, to maintain a constant discharge, a large cross-sectional area is required if the hydraulic conductivity is low. Based on this relationship, a substantial discharge from the low-permeability Star Point Sandstone can occur if there is a sufficiently large cross-sectional area through which groundwater discharge can occur. It is believed that the large network of fracture planes that make up the regional fracture network may provide the surface area necessary to drain the water stored in the matrix of the Star Point Sandstone at a reasonable rate.

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Inactive-zone groundwater systems in the Star Point Sandstone occur in isolated partitions that are not in hydraulic communication with the land surface or shallow overlying activezone groundwater systems that support springs and seeps and provide baseflow to streams. Therefore, groundwater being removed from the Star Point Sandstone is almost entirely groundwater that is being removed from storage. Because inactive-zone groundwater systems are not in hydraulic communication with the land surface or shallow, active-zone groundwater systems, groundwater being removed from the Star Point Sandstone is likely not being replenished by recharge from adjacent or overlying groundwater systems or from infiltration of surface waters. For the same reason, it is highly unlikely that springs, seeps, or perennial streams overlying depressurized portions of Star Point Sandstone would be impacted as a result of the local depressurization of the Star Point Sandstone in the Skyline Mine permit and adjacent area.

The fault-related, inactive-zone groundwater systems in the Star Point Sandstone are not part of a regionally continuous aquifer in the broad sense. Groundwater in the inactive zone occurs primarily in isolated partitions created by the discontinuous nature of bedrock hydrostratigraphic horizons. Locally, the size of the partitions may be large because of hydraulic interconnectedness caused by secondary fracture porosity. However, the size of fracture-enhanced groundwater partitions are constrained by hydrogeologic features such as lithologic pinch-outs, bounding faults that juxtapose permeable zones against impermeable lithologies, fracture discontinuities, or lateral variation in fracture density and aperture.

The precise recharge locations for the fracture-related Star Point Sandstone groundwater systems are not known. However, it is important to keep in mind that groundwater rarely travels via pure piston flow. Rather, groundwater arriving at a spring, well, or in-mine location is usually a mixture of water molecules that recharged at different times and in different locations. Based on the considerable variability of the radiocarbon ages of faultrelated in-mine groundwaters (Table 2), it is apparent that there have been several recharge episodes over the past several thousand years. These recharge events could have occurred at many different locations. Although the groundwater recharge locations are unknown, it seems plausible that the recharge may have occurred in the highland regions south and east of the Skyline Mine workings. In order for the hydraulic head on the Star Point Sandstone to achieve the approximate elevation of 8,500 feet, the precipitation and groundwater recharge must have occurred at or above this elevation.

Stable isotopic  $\delta^2$ H and  $\delta^{18}$ O data indicate that the groundwater in the fault-related in-mine inflows is meteoric in origin (Figure 3). This indicates that the recharge water fell as precipitation and is not magmatic in origin. As discussed above, it is not possible with the existing data to determine with certainty where the recharge occurred.

Based on the conceptual model of the active-zone and inactive-zone groundwater flow regimes presented by Mayo and Morris (2000), groundwater in the Star Point Sandstone (under undisturbed conditions) was not part of an actively circulating flow system. Rather, as evidenced by the antiquity of the groundwater (up to 26,000 years) groundwater systems in

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the Star Point Sandstone are part of the inactive-zone. The large fault-related inflows into the Skyline Mine are sustained by decreases in storage in the Star Point Sandstone. Corresponding recharge to the formation in up-gradient locations is not occurring, as is evidenced by the steadily declining water levels in the Star Point Sandstone. This is also evidenced by the lack of observable or quantifiable diminution of spring discharges in the surrounding area. Based on this information and on the antiquity of the fault-related water discharged into the mine, it is believed that little or no recharge to the fault-related groundwater system is occurring.

#### 6.4 Potentiometric levels in the fault-related groundwater system.

Groundwater potentiometric surface maps are useful to assist in determining groundwater flow directions and velocities in homogeneous aquifers. In order to construct a valid potentiometric surface map, it is required that the wells from which aquifer data are collected are completed in the same hydrostratigraphic horizon. In most locations in the Wasatch Plateau coal district it is not possible to create meaningful potentiometric surface contour maps of inactive-zone groundwater systems, even where abundant potentiometric data are available. This is because 1) groundwaters in individual partitions may not be in hydraulic communication with adjacent partitions or only in weak hydraulic communication, 2) in dipping, stratified sedimentary rock with interbedded lower permeability and higher permeability horizons, vertical hydraulic gradients in confined systems tend to develop, and 3) bedrock fracture densities and aperture sizes commonly exhibit vertical and horizontal heterogeneity in their spatial extent. Thus, for these reasons, attempts to construct potentiometric surface maps under these conditions may result in an incorrect interpretation of groundwater conditions in the aquifer.

However, water level declines in Star Point Sandstone monitoring wells have been observed over an area of several square miles that appear to be related to the local depressurization of the Star Point Sandstone from fault-related groundwater inflows into the Skyline Mine. Potentiometric data from Star Point Sandstone wells in the area have been plotted and a series of approximate potentiometric maps for the fault-related groundwater system in the Star Point Sandstone have been created (Figure 4). These maps, although only general estimations of potentiometric conditions in the local fracture system in the Star Point Sandstone, are useful in providing a general characterization of the local depressurization of the Star Point Sandstone and in assisting future mine dewatering planning.

#### 6.5 Potential for modern recharge to the fault-related groundwater system

There has been considerable speculation that the large groundwater inflows in the Skyline Mine originate from leakage of shallow, active-zone sources overlying the mine workings. While a minor component of modern recharge cannot be completely ruled-out, several lines of evidence indicates that the fault-related groundwater is not derived from shallow, active-zone sources.

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Stable and unstable isotopic data from Electric Lake, active-zone springs, and streams, indicate that these systems are not a primary source of the water in the fault-related Star Point Sandstone groundwater systems encountered in the Skyline Mine. As discussed previously, Active-zone groundwaters and surface waters in the region contain abundant tritium, have modern radiocarbon ages, and contain anthropogenic carbon. In contrast, the fault-related groundwaters have very old radiocarbon ages and contain little or no tritium (Table 2). In order to validate the conclusions that the isotopic compositions of groundwaters encountered in the fault-related Star Point Sandstone groundwater system are statistically different from those in Electric Lake, two tailed T-Tests were performed. The T-tests confirm that the fault-related groundwaters are statistically different from the Electric Lake waters based on each of their stable isotopic  $\delta^2 H$ ,  $\delta^{18} O$  content and unstable tritium and radiocarbon contents at the 95% confidence level. The results of the T-tests are summarized below.

Results of T-Test analyses comparing fault-related groundwater inflows and Electric Lake water

Population	$\delta^2 \mathbf{H}$	$\delta^{10}$ <b>O</b>	tritium	radiocarbon
Fault-related	Populations	Populations	Populations	Populations
groundwater	statistically	statistically	statistically	statistically
inflow water	distinguishable	distinguishable	distinguishable	distinguishable
including JC-1				
compared to	Probability:	Probability:	Probability:	Probability:
Electric Lake	>99.9%	>99.9%	>99.9%	>99.9%
water				
10 Left Sump and	Populations	Populations	Populations	Populations
JC-1 groundwater	statistically	statistically	statistically	statistically
compared to	distinguishable	distinguishable	distinguishable	distinguishable
Electric Lake				
water	Probability:	Probability:	Probability:	Probability:
	>99%	>99%	>99.9%	>99.9%

The lack of vertical communication between vertically juxtaposed inactive-zone groundwater systems in the study area is demonstrated by the hydrographs of wells 79-53-1A and 79-35-1B, a nested monitoring well pair in Burnout Canyon (Figure 5). Well 79-35-1B is completed in the Blackhawk Formation above the mined coal seams. Well 79-35-1A is completed in the Star Point Sandstone below the currently mined coal seams. It is known that the well bore at 79-35-1A intersected a significant fault when it was drilled (Vaughn Hansen Associates, 1979). In response to the nearby major groundwater inflows into the Skyline Mine that occurred during 2001 and 2002, the potentiometric level in 79-35-1A has experienced a continuous decline. In contrast, the potentiometric level in 79-35-1B, which is isolated from the underlying Star Point Sandstone by low-permeability rocks of the Blackhawk Formation, has remained very stable during the same period (Figure 5). This

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demonstrates that vertical flow through the Blackhawk Formation overlying faulted portions of the mine workings is not occurring.

Likewise, solute and isotopic data indicate the Electric Lake cannot be a major source of the fault-related groundwater that is flowing into the Skyline Mine. Based on the solute compositions of Electric Lake water and water from the fracture system associated with the 10 Left inflow, it is readily apparent that the water flowing into the mine is chemically distinct from that in Electric Lake. The recent solute chemical composition of the 10 Left inflow water and Electric Lake water are summarized in Table 5. Most notably, the average chloride content of the water in Electric Lake (6.5 mg/l) is nearly four times greater than the average chloride content in the fault-related systems (1.7 mg/l). Chloride is considered a conservative species, meaning that the constituent is not attenuated from a groundwater system, other than by dilution (Fetter, 1988). In other words, there is no mechanism whereby the chloride in the lake water could be removed were it to flow through a fault system, regardless of the residence time in the fracture. Although the calcium contents of the in-mine and lake water are similar (Table 5), the magnesium and bicarbonate content of the waters are dissimilar. The average bicarbonate content of the fault-related groundwater (216 mg/l) is approximately 50% greater than the average lake content (148 mg/l). The average magnesium content of the fault-related groundwater (23.0 mg/l) is more than three times that of the average lake water (7.5 mg/l). Mineral saturation indices for calcite, dolomite, and gypsum are listed in Table 5. Saturation indices at  $0 \pm 0.1$  indicate that a water is saturated with respect to that mineral. Waters at saturation with respect to a mineral will not dissolve additional quantities of that mineral or precipitate the mineral should the water come into contact with it. Waters with a saturation index less than 0 are under saturated with respect to that mineral. Under saturated waters have a thermodynamic tendency to dissolve that mineral if it comes into contact with the water. Waters with a saturation index above about 0.1 are supersaturated and have a tendency to precipitate that mineral. Electric Lake waters are supersaturated with respect to both calcite and dolomite, indicating that they have the thermodynamic tendency to precipitate rather than dissolve those minerals. Thus, in the absence of an external source of CO<sub>2</sub>, such as deep, metamorphic CO<sub>2</sub> or bacterially mediated organic decay (both of which are considered unlikely in the sandstones of the Star Point Sandstone), the lake water cannot dissolve carbonate minerals (likely the only plausible mechanism whereby the groundwater could acquire additional bicarbonate and magnesium) along a groundwater flowpath regardless of the residence time in the fracture system. That external sources of CO<sub>2</sub> have not influenced the carbon history of the fault-related groundwater is apparent in the  $\delta^{13}$ C composition of these groundwaters (Table 2). As discussed previously, groundwaters with  $\delta^{13}$ C compositions near -10% are consistent with the dissolution of carbonate minerals in the presence of soil-zone CO<sub>2</sub> gas. Groundwaters that have been influenced by metamorphic  $CO_2$  or by biogenic  $CO_2$  will likely have  $\delta^{13}C$ contents that deviate significantly from -10%.

The dissolved oxygen content of groundwater in Electric Lake (average 7.0 mg/l) is more than 10 times greater than that measured in the in-mine fault-related groundwaters (average 0.60 mg/l). Although dissolved oxygen can readily be removed from a groundwater system through chemical or biological processes, it seems unlikely that this would occur if the lake

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water were moving rapidly and in large volumes through a sandstone fracture system directly into the mine workings.

The evidence presented above clearly demonstrates that the in-mine fault-related groundwater is not the same as the water in Electric Lake. It is also evident that Electric Lake water (without mixing with other waters) cannot chemically evolve into groundwater with a chemical composition like that of the fault-related groundwater in the hydrogeologic environment of the Skyline Mine area.

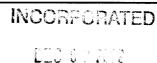
#### 6.6 Potential modern component of recharge

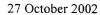
When well JC-1 was sampled in May 2002, a tritium concentration of approximately 1 TU was detected. In all subsequent samplings of the well, tritium concentrations of approximately 1 TU have also been measured (Table 2). Tritium concentrations in excess of about 1 TU, which can be indicative of a component of recharge within the past 50 years (Clark and Fritz, 1997), have also been encountered in a single fault-related location in the Skyline Mine (Table 2). At other fault-related inflows in the Skyline Mine, tritium concentrations have generally been substantially below 1 TU, indicating that these groundwaters have been isolated from the surface for at least the past approximately 50 years (Table 2).

Tritium concentrations on the order of 1 TU may be explained by two different mechanisms. A single slug of groundwater that migrated via piston flow and recharged in 1952 with a tritium content of 20 TU would have a tritium content of approximately 1.25 TU in 2001. Alternatively, a large reservoir of groundwater with 0 TU that was mixed with a much smaller fraction of modern, tritiated water could acquire a tritium concentration near 1 TU. The tritium concentration of such a mixed groundwater would be a function of 1) the tritium concentration of the modern recharge source, 2) the fraction of modern water relative to the old "dead" component, and 3) the time elapsed since the introduction of the modern recharge component.

Based on the radiocarbon content of the groundwaters from the Skyline Mine, it is evident that the trace amounts of tritium found in the 10 Left Sump and JC-1 groundwaters were most likely derived by the latter mechanism described above. The radiocarbon contents of all fault-related inflows (including 10 Left Sump and JC-1) indicate that most of the groundwater recharged many thousands of years ago (Table 2). Thus, the water sampled at JC-1 and the 10 Left Sump in-mine area cannot have originated from a single slug of recharge water. Rather, there must be a component that recharged many thousands of years ago and a relatively small component that recharged in the past approximately 50 years.

With the existing data, it is not possible to determine with certainty the source of the small amount of modern recharge in the 10 Left Sump area. However, in a general sense, it may be stated that the modern water is likely derived from either 1) leakage from shallow or intermediate depth, active groundwater systems that surround the coal seams in the vicinity of the fault inflow, 2) losses from nearby surface water systems that contain abundant tritium, or





3) a combination of both of these sources. Currently, there is considerable speculation regarding the possibility that there is leakage of large amounts of surface water from Electric Lake into the 10 Left inflow in the Skyline Mine. Although the precise origin of the small modern water component has not been determined, it is clearly evident that Electric Lake water cannot be a primary source of the fault-inflows.

As described above, groundwater flow through the Star Point Sandstone occurs primarily through fracture openings and groundwater flow through the matrix of the sandstone occurs only at a very slow rate. Based on these findings, it is apparent that large volumes of leaking Electric Lake water cannot be the source of the large fault-related inflows in the Skyline Mine. If Electric Lake water was flowing through fractures directly to the 10 Left area, it would be anticipated that the "pulse" of lake water would arrive at the mine in a short period of time. This conclusion is reached because the fracture system in the local area between the lake and the mine has only limited storage potential. Thus, it would be necessary for the potential large volumes of lake water to migrate very rapidly through the fracture network to accommodate continued water movement from the lake into the fracture system. This condition can be likened to the movement of cars on the interstate freeway during rush hour. Because the total surface area available for cars is limited, the only way to move a large number of vehicles over large distances it to move them rapidly. Calculations of the potential storage capacity of the fracture network in the vicinity of the 10 Left inflow and Electric Lake indicate that were a large inflow of lake water to be migrating through the fracture system, that water should have arrived in the mine in a period of several hours to several days (based on the amount of time required to fill the fracture volume). Based on stable isotopic evidence, solute chemical evidence, tritium concentrations, and radiocarbon contents, it is clear that this is not occurring (i.e., there is not a large slug of modern recharge water anywhere in the Skyline Mine). Similarly, if Electric Lake water were migrating through the pore spaces of the Star Point Sandstone, based on the low hydraulic conductivity of the rock (1.3 x 10<sup>-6</sup> to 2.3 x 10<sup>-6</sup> cm/sec), it is calculated that the time required for this water to reach the mine workings would likely be measured in the hundreds or thousands of years. Clearly, the lake water could not have migrated through the sandstone pore spaces in the short time that has elapsed since the fracture system was first encountered in the mine.

Based on the assumption that there could be a small component of modern recharge in the fault-related groundwater in the 10 Left area, it is possible to calculate the approximate magnitude of that component using a flow-weighted partitioning of the old and modern components of the groundwater using tritium contents. These calculations are summarized in below.

Calculations of the possible percentage of modern recharge in the 10 Left fault-related inflow have been performed using the following inputs:

- 1. Time-series tritium contents of groundwater encountered in the 10 Left inflow area
- 2. The average tritium content of active-zone groundwaters and surface waters in the Skyline Mine and adjacent areas

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In order to determine a reasonable range of possible values for the modern recharge component in the 10 Left groundwater system, a series of calculations have been performed using three assumptions. The assumption used in the first calculation assumes that the modern recharge water component is consistent with the average of tritium concentrations sampled from active-zone springs and streams over the past 10 years in the Skyline Mine region. The assumption used in the second calculation assumes that the modern recharge component has a tritium content consistent with the average of that measured in Electric Lake over the past year. The third calculation assumes that the modern recharge component has a tritium content equal to the average of the historic active-zone springs and streams and Electric Lake water. These calculations are summarized on Tables 6 and 7 and are shown graphically in Figure 6. It is apparent in Figure 6 that the magnitude of the modern recharge component to the 10 Left area is small. It is calculated that the maximum modern component in the fault-related system could range from approximately 6.9 to 12.4 percent. It is also apparent that since routine sampling of the 10 Left groundwater system began in May 2002, the percentage of modern recharge in the groundwater system has not increased.

Based on the potential modern recharge percentage calculations presented above, it is determined that of the total inflow to the 10 Left region (approximately 3,800 gpm), a maximum of approximately 262 to 471 gpm could have originated as modern recharge. Inasmuch as Canyon Fuel has been pumping approximately 2,200 gpm from the 10 Left groundwater system into Electric Lake since September 2001, the potential net impact to the Electric Lake watershed, were it occurring, would be completely mitigated by the current pumping. Additionally, groundwater that would not otherwise be available for use without the pumping activity is being added to the watershed. Since October 2002, PacifiCorp has increased the pumping rate at JC-1 to more than 4,000 gpm. Thus, currently, the amount of groundwater being pumped into Electric Lake from JC-1 represents a volume approximately one order of magnitude greater than that which could potentially be derived from modern sources. It should be noted that there is currently **no** information that would indicate that the potential modern component in the fault-related mine inflows is directly or indirectly related to losses from Electric Lake.

## 7.0 Likely Impacts to the Hydrologic Balance

Because the springs and streams in the permit area discharge almost exclusively from active-zone groundwater systems, while the fault-related in-mine groundwater inflows are from inactive-zone groundwater systems that are generally not in communication with the surface, the potential for detrimental impacts to the hydrologic balance is believed to be minimal.

To date, while a significant depressurization of the Star Point Sandstone has already occurred in the vicinity of the mine, no impacts to spring discharge rates or water quality that could be attributed to this depressurization have been observed. Likewise, detrimental impacts to stream discharge rates and water quality have not occurred.

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Rather, the impacts of the fault-related groundwater inflows and associated pumping on the local watersheds during the ongoing period of serious drought have been positive. The ancient groundwater encountered in the mine is currently being pumped to both Scofield Reservoir in the Price River drainage, and to Electric Lake in the Huntington Creek drainage. This water is water that otherwise would likely not naturally discharge to the surface at any significant rate. Thus, the pumping of fault-related groundwaters to the surface is making significant quantities of water available for use that, otherwise, would not be available.

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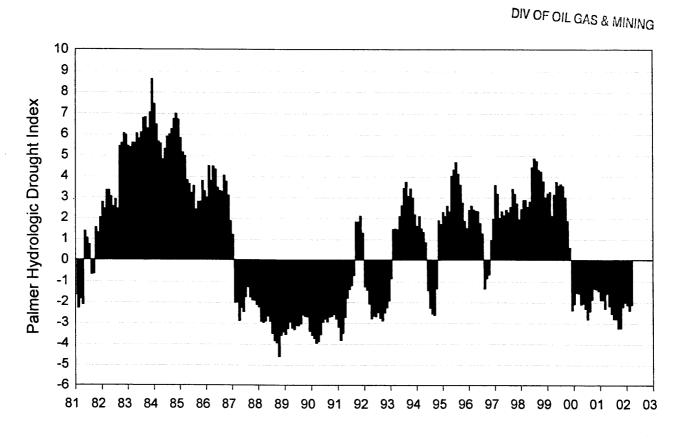
Vaughn Hansen Associates, 1979, Hydrologic inventory of the Skyline property and adjacent areas, Carbon and Emery Counties, Utah: unpublished consulting report, October 1979, Salt Lake City, 186 p., Appendices.

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-1 to -2 Mild Drought

-2 to -3 Moderate Drought

-3 to -4 Severe Drought -4 to -5 Extreme Drought

1 to 2 Mild Wet Spell 2 to 3 Moderate Wet Spell

3 to 4 Severe Wet Spell

4 to 5 Extreme Wet Spell

Figure 1 Palmer Hydrologic Drought Index, Utah Region 5 (Skyline Mine area).

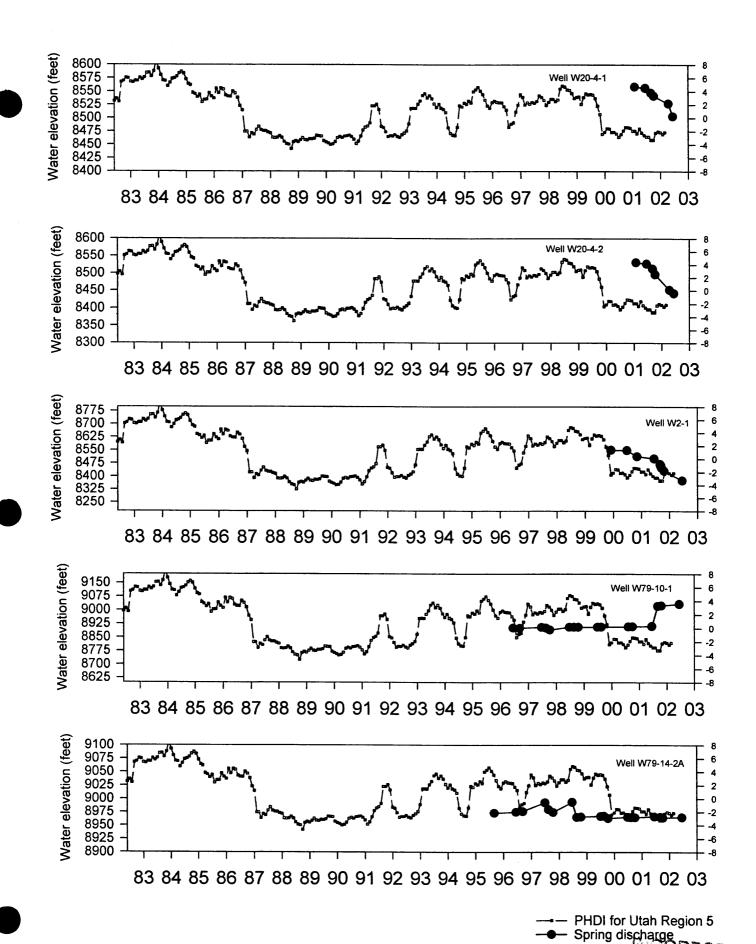
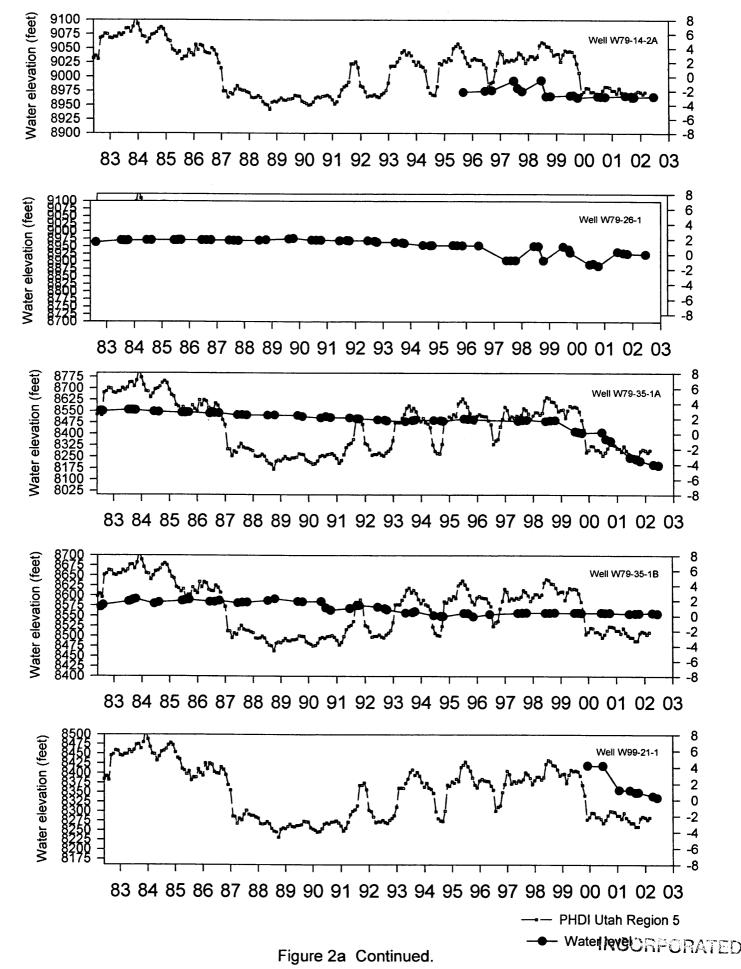


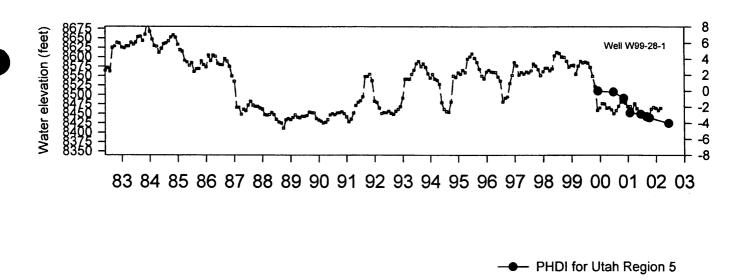
Figure 2a Water level hydrographs for wells in the Skyline Mine area.

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- Well elevation

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Figure 2a Continued.

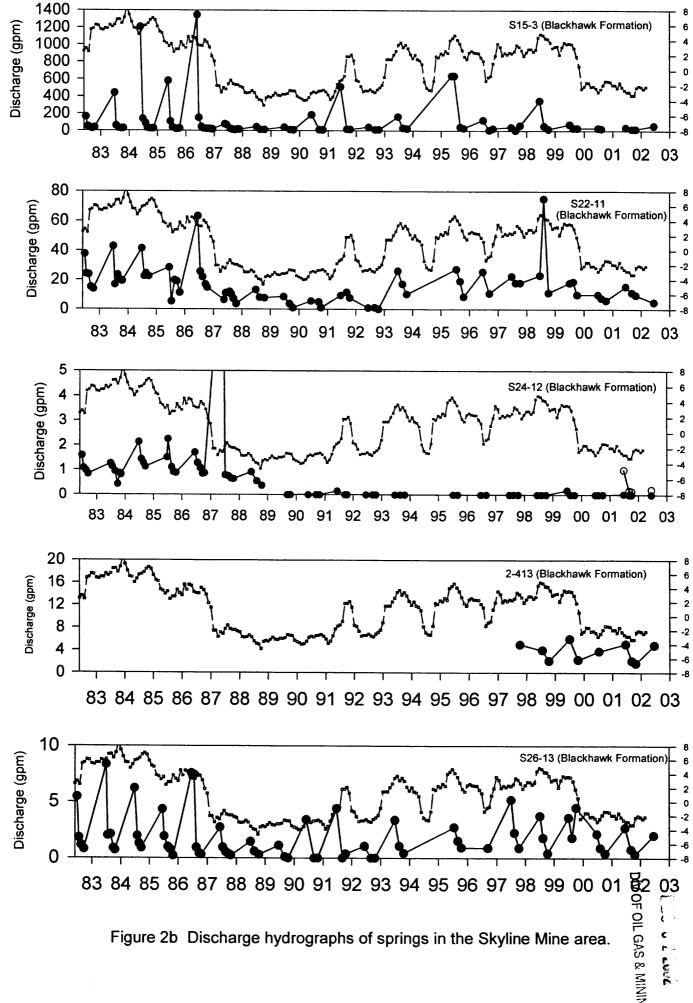
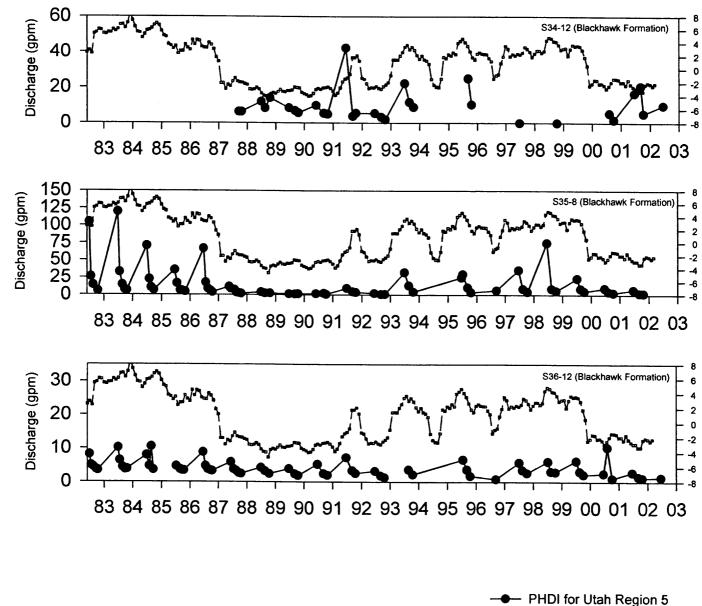
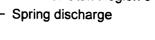


Figure 2b Discharge hydrographs of springs in the Skyline Mine area.





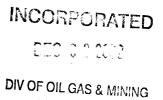
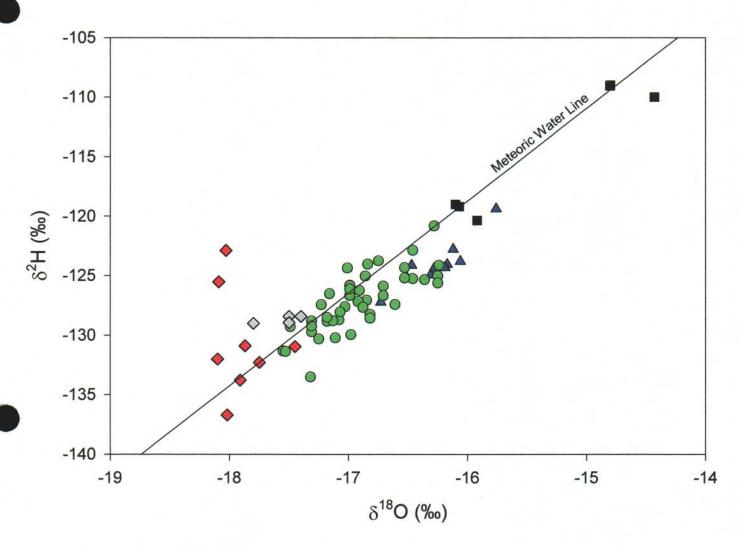


Figure 2b Continued.



- Springs (active-zone)
- ▲ Streams
- In-mine fault-related groundwater
- ♦ JC-1 fault-related groundwater
- Electric Lake

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Figure 3 Plot of  $\delta^2 h$  and  $\delta^{18} O$  for groundwaters and surface waters in the Skyline Mine area.

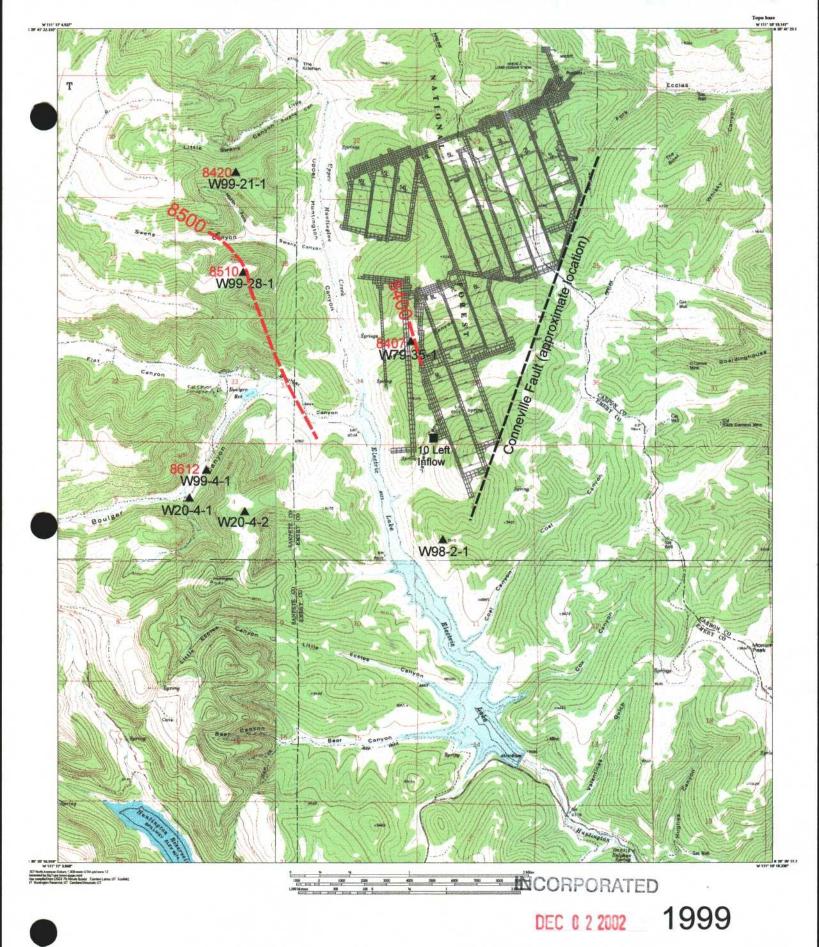
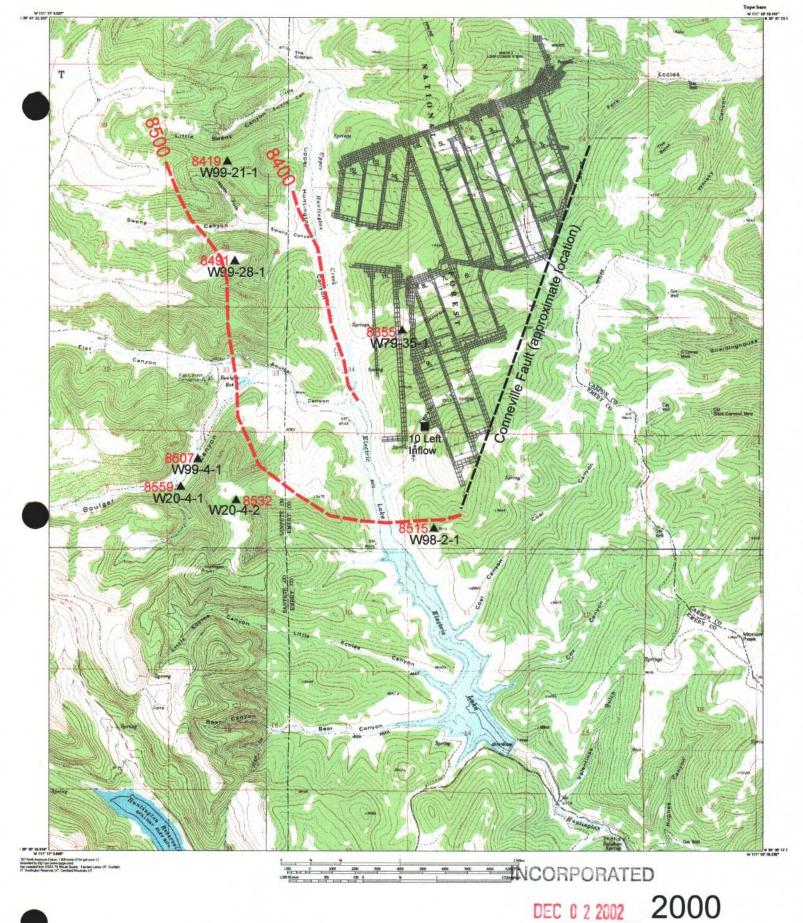


Figure 4a Approximate potentiometric levels in the fault-related Star Point Sandstone groundwater system during late 1999.



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Figure 4b Approximate potentiometric levels in the fault-related Star Point Sandstone groundwater system during late 2000.

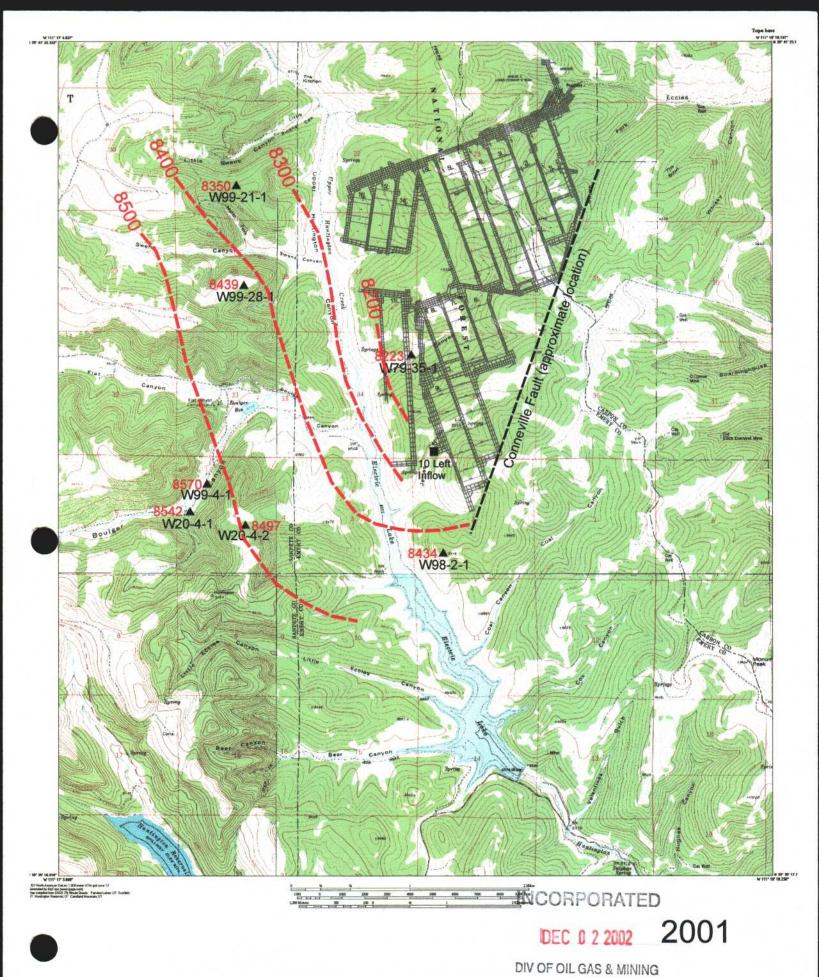


Figure 4c Approximate potentiometric levels in the fault-related Star Point Sandstone groundwater system during late 2001.

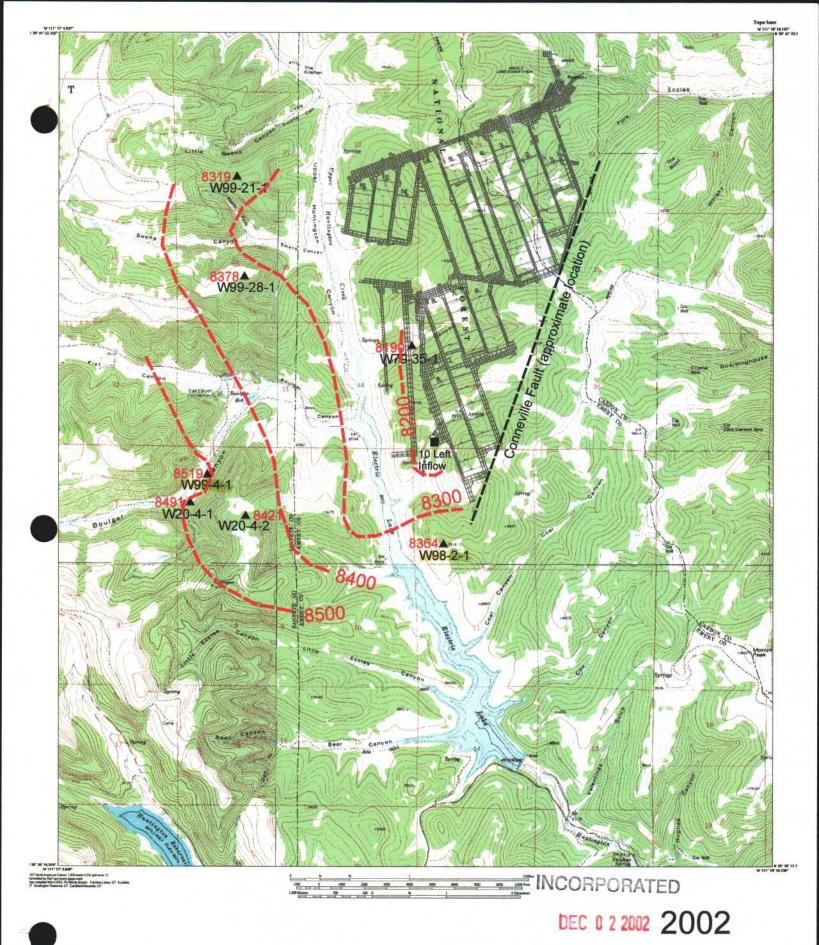


Figure 4d Approximate potentiometric levels in the fault-related Star Point Sandstone groundwater system during late 2002.

**TABLES** 

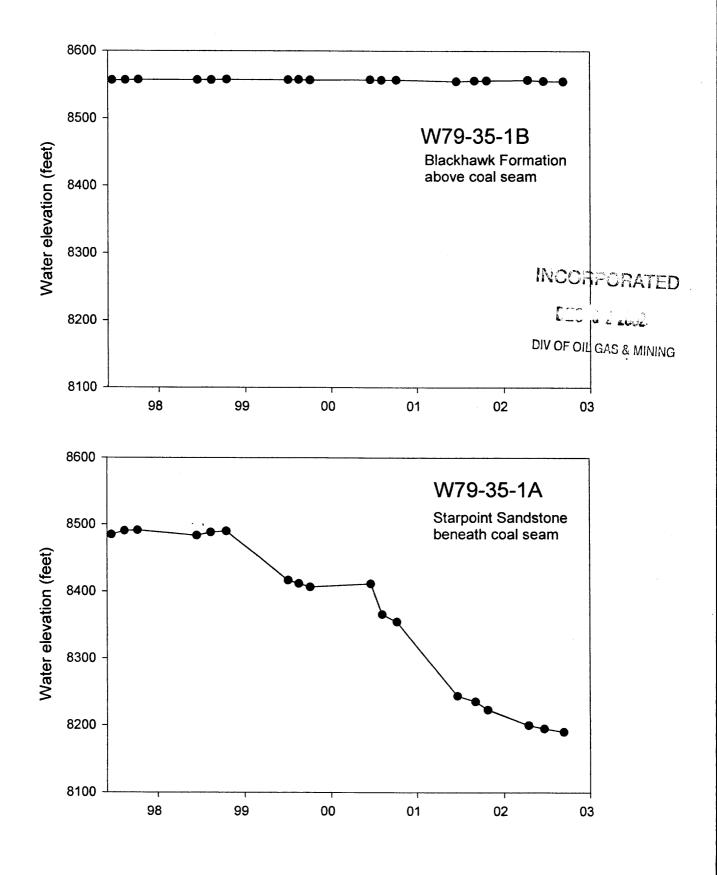
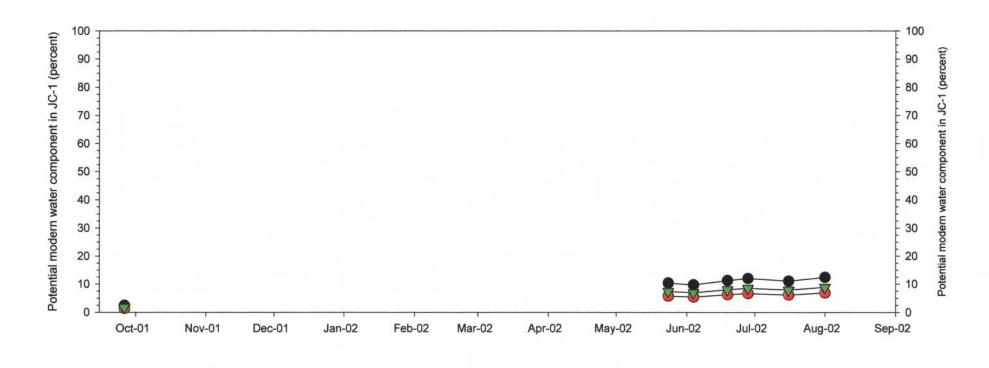


Figure 5 Comparison of water level declines at the nested piezometers at W79-35-1.



All calculations assume mine water with tritium content of 0.0 TU

Assuming modern recharge water with tritium content similar to that of average 2001-2002 Electric Lake composition (9.81 TU)

- Assuming modern recharge water with tritium content similar to that of average spring and stream composition (17.58 T.U)

-W- Assuming modern recharge water with tritium content similar to the average of Electric Lake water and springs and streams (13.70 TU)

Figure 6 Plot of potential modern water component in the 10 Left discharge based on tritium content

Table 1 Water levels in monitoring wells in the Skyline Mine area.

7/15/1995 67.90 8953.90 10/15/1994 244.70 8484.20 10/15/1994 178.20 8548.70 9/5/1995 68.50 8953.30 7/15/1995 230.20 8498.70 7/15/1995 170.60 8556.30

9/5/1995 232.40 8496.50

6/19/1997 118.50 8903.30 6/19/1997 244.20 8484.70 6/15/1996 173.00 8553.90

10/9/1997 237.70 8491.20

6/15/1998 245.40 8483.50

8/13/1998 240.70 8488.20

10/17/1998 239.00 8489.90

7/5/1999 312.20 8416.70

10/6/1999 322.30 8406.60

6/20/2000 317.30 8411.60

8/7/2000 363.00 8365.90

10/9/2000 374.00 8354.90

6/19/2001 484.90 8244.00

9/3/2001 493.30 8235.60

10/25/2001 505.5 8223.4

6/19/2002 533.71 8195.19

9/2/2002 535.9 8193

11/14/2002 538.97 8189.93

3/10/2003 554.45 8174.45

8/13/1997 118.44 8903.36 8/15/1997 238.50 8490.40

9/19/1999 81.20 8940.60 8/19/1999 317.30 8411.60

11/15/1995 235.20 8493.70 11/15/1995 179.00 8547.90

4/15/2002 528.75 8200.15 10/25/2001 170.70 8556.20

9/5/1995 171.10 8555.80

6/19/1997 170.10 8556.80

8/15/1997 169.80 8557.10

10/9/1997 169.40 8557.50

6/15/1998 169.60 8557.30

8/13/1998 169.60 8557.30

10/17/1998 169.00 8557.90

7/5/1999 169.40 8557.50

8/19/1999 169.10 8557.80

10/6/1999 169.90 8557.00

6/20/2000 169.10 8557.80

8/7/2000 170.00 8556.90

10/9/2000 169.50 8557.40

6/19/2001 171.80 8555.10

9/3/2001 170.90 8556.00

4/15/2002 169.75 8557.15

6/19/2002 171.25 8555.65

9/2/2002 171.73 8555.17

11/14/2002 171.05 8555.85 1/16/2003 172.11 8554.79 2/1/2003 173.81 8553.09 3/9/2002 176.91 8549.99

11/15/1995 68.70 8953.10

6/15/1996 69.00 8952.80

10/12/1997 118.44 8903.36

6/15/1998 70.30 8951.50

8/13/1998 71.00 8950.80

10/17/1998 118.90 8902.90

7/5/1999 71.90 8949.90

10/6/1999 91.80 8930.00

6/20/2000 131.70 8890.10

8/7/2000 129.00 8892.80

10/9/2000 136.70 8885.10

6/19/2001 89.00 8932.80

9/3/2001 93.10 8928.70

10/25/2001 95.50 8926.30

6/19/2002 97.60 8924.20

9/15/2002 99.78 8922.02

11/14/2002 100.02 8921.78

Table 1 Water leve	ls in monitoring well	s in the Skyline Mine	area.					1		
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								İ		
W79-26-1	W79-35-1A	W79-35-1B	W79-10-1	W79-14-2A	99-21-1	99-28-1	20-4-1	ļ	20-4-2	W2-1
Date Depth Elevation	Date Depth Elevation	Date Depth Elevation	Date Depth Elevation	Date Depth Elevation	Date Depth Elevation	Date Depth Elevation		Elevation	Date Depth Elevation	Date Depth Elevation
8/15/1982 58.30 8963.50 7/15/1983 52.20 8969.60	7/15/1982 177.50 8551.40 8/15/1982 179.00 8549.90	7/15/1982 154.70 8572.20	6/15/1996 480.30 8902.50	9/5/1995 78.70 8973.00	12/9/1999 926.50 8419.50	12/9/1999 841.00 8510.00			/29/2001 1022.00 8532.00	12/3/1999 720.00 8551.40
8/15/1983 52.50 8969.30	7/15/1983 171.50 8557.40	8/15/1982 150.40 8576.50	9/11/1996 482.19 8900.61	6/15/1996 76.90 8974.80	6/26/2000 927.00 8419.00	6/26/2000 843.70 8507.30	6/18/2001 317.4		/18/2001 1026.5 8527.5	6/26/2000 722.20 8549.20
9/15/1983 52.80 8969.00	8/15/1983 171.70 8557.20	7/15/1983 141.70 8585.20 8/15/1983 139.60 8587.30	6/23/1997 477.20 8905.60	9/12/1996 75.66 8976.04	1/29/2001 990.00 8356.00	11/8/2000 860.10 8490.90		4	9/3/2001 1040 8514	11/8/2000 756.20 8515.20
10/15/1983 52.20 8969.60	9/15/1983 171.20 8557.70	9/15/1983 136.80 8590.10	8/15/1997 480.70 8902.10 10/9/1997 491.10 8891.70	6/27/1997 59.06 8992.64	6/18/2001 990.7 8355.3	1/29/2001 899 8452	10/8/2001 332.1		0/8/2001 1056.9 8497.1	6/18/2001 768.90 8502.50
6/15/1984 51.60 8970.20	10/15/1983 172.40 8556.50	10/15/1983 135.90 8591.00		8/15/1997 71.90 8979.80	9/3/2001 996.8 8349.2	6/18/2001 902.3 8448.7	1/3/2002 346.5	:	/16/2002 1101.5 8452.54	9/5/2001 800.1 8471.3
8/15/1984 51.20 8970.60	6/15/1984 182.20 8546.70	6/15/1984 147.40 8579.50	6/22/1998 476.30 8906.50 8/22/1998 476.20 8906.60	10/12/1997 77.30 8974.40	10/8/2001 996.1 8349.9	9/3/2001 908.7 8442.3	6/12/2002 370.5	1	/13/2002 1111 8443.05	9/10/2001 808.4 8463
6/15/1985 51.20 8970.60	8/15/1984 183.70 8545.20	8/15/1984 143.80 8583.10	10/17/1998 476.00 8906.80	6/22/1998 58.20 8993.50	4/15/2002 1005.79 8340.21	10/8/2001 911.7 8439.3			/27/2002 1133.5 8420.53	9/14/2001 807.7 8463.7
7/15/1985 51.00 8970.80	6/15/1985 188.30 8540.60	6/15/1985 140.10 8586.80	6/29/1999 475.30 8907.50	8/22/1998 86.40 8965.30 10/17/1998 85.90 8965.80	6/12/2002 1010.3 8335.7 9/24/2002 1026.74 8319.26	6/12/2002 926.25 8424.75	11/5/2002 389.75	<b>84</b> 84.25 10	0/16/2002 1134 8420	9/20/2001 819.4 8452
8/15/1985 50.90 8970.90	7/15/1985 187.20 8541.70	7/15/1985 139.10 8587.80	8/17/1999 475.10 8907.70	7/6/1999 84.70 8967.00	11/14/2002 1029.04 8316.96	9/24/2002 973.7 8377.3		1		10/23/2001 837.5 8433.9
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8/15/1987 52.30 8969.50	6/15/1987 204.80 8524.10	6/15/1987 145.60 8581.30	6/17/2002 348.2 9034.6	6/18/2001 85.3 8966.4				l		
10/15/1987 52.80 8969.00	8/15/1987 203.60 8525.30	8/15/1987 144.30 8582.60	9/2/2002 366.7 9016.1	9/5/2001 85.9 8965.8				)		
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8/15/1989 47.00 8974.80	10/15/1988 205.30 8523.60	10/15/1988 135.40 8591.50		9/9/2002 86.5 8965.2				į.		
10/15/1989 45.30 8976.50	8/15/1989 207.60 8521.30	8/15/1989 141.80 8585.10		11/5/2002 87.6 8964.1				Ì		
6/15/1990 50.80 8971.00	10/15/1989 214.60 8514.30	10/15/1989 142.60 8584.30						(		
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6/15/1991 52.80 8969.00	10/15/1990 221.20 8507.70	10/15/1990 163.00 8563.90						)		
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9/15/1992 54.40 8967.40	6/15/1992 236.50 8492.40	6/15/1992 155.30 8571.60								
10/15/1992 57.50 8964.30	9/15/1992 238.20 8490.70	9/15/1992 159.00 8567.90								
6/15/1993 58.20 8963.60	10/15/1992 243.30 8485.60	10/15/1992 161.90 8565.00						(		
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10/15/1993 61.60 8960.20	9/15/1993 239.90 8489.00	9/15/1993 168.50 8558.40						1		
6/15/1994 67.80 8954.00	10/15/1993 237.20 8491.70	10/15/1993 166.40 8560.50						<u> </u>		
9/15/1994 68.60 8953.20	6/15/1994 239.70 8489.20	6/15/1994 176.10 8550.80						ţ		
10/15/1994 68.50 8953.30	9/15/1994 241.50 8487.40	9/15/1994 177.80 8549.10						i		

sle 2 Isotopic compositions of groundwaters and surface waters in the Skyline Mine a

Mean residence time		modem modem modem modem modem modem	modern modern modern	modern modern modern modern	3,000 mixed w/modern 9500 17000 8500	10500	16500 10500 2500
(THIUM (TU)	218 15.8	14.9 10.5 10.5 12.9 30 30 30 14 15 15 10 31	13.9 11.1 18.4 15.1	18.8 20.4 20.4 18.1	1.61 1.73 0.21 0.02 0.05	0.3 0.3 0.28 0.28 0.28 0.28 0.28	6.7° 0.12 0.26
"C (pmc)		73.18 73.18 88.18 89.08 89.08 71.57 71.57 71.57	87.36 107.14 100.4 82.78	80.12 62.4 75.49 78.26 85.16	39.56 18.29 7.06 20.99	21.4 14.1 15.4 21.36 28.35	5.6 14.1 41.5
8 <sup>13</sup> C (%)		13.8 12.4 12.3 12.3 12.3 12.3 12.3 12.3 12.3 12.3	-15.0 -12.45 -12.4 -14.6 -12.0 -12.7	12.0 13.2 13.2 12.1 12.1 12.1 13.0 13.3	-10.5 -12.5 -14.7	64 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	-10.8 -10.8
5 (%)		·	+12.1 +8.5 +5.7 +8.1 +13.5 +10.4	+10.4 +14.75 +16.5 +5.1 +10.6 +9.1 +12.9 +10.6	-1.5 -0.7 +12.7 +19.45	6.7 6.2 17.2 16.6 13.9 19.3 8.9 19.4 14.8 14.8 16.8 113.9	+19.4
6.0(%)	-16.28 -16.31 -123.8 -15.76 -12.72 -16.62 -124.05 -124.13	6.88					•
5⁴H (‰)	-124.37 -124.94 -16.06 -119.38 -16.17 -124.99 -16.17	28.79 20.81				Λο Δουσομούς του συνακούς το	; 
Date	10/17/1995 5/22/1996 10/1/1997 10/1/1998 10/1/1997 17/1/1998 10/1/1997 17/1/1998	10/6/1997 10/2/1998 10/2/1998 10/2/1998 10/2/1998 10/2/1999 7/2/1999 7/2/1999 10/1/1997 7/2/1999 10/1/1997 7/2/1999 10/1/1997 10/1/1997 10/1/1998 10/1/1997 10/1/1998 10/1/1997 10/1/1998 10/1/1998 10/1/1999 10/1/1999 10/1/1999 10/1/1999 10/1/1999 10/1/1999 10/1/1999 10/1/1999 10/1/1999 10/1/1999 10/1/1999 10/1/1999 10/1/1999 10/1/1999 10/1/1999	6/6/1996 6/5/1996 6/5/1996 6/6/1996 6/6/1996 6/6/1996	10/17/1995 10/18/1995 10/18/1995 10/18/1995 10/18/1995 10/18/1995 10/18/1995 10/18/1995	10/17/1995 5/22/1996 7/23/1996 7/23/1996	100 1 200 1	5/8/1993 5/8/1993 5/8/1996 5/8/1996
Site	2.5.5.5.5.5.5.5.5.5.5.5.5.5.5.5.5.5.5.5	Springs, Flat Canyon Tract 2-413 2-413 7-242 7-242 7-242 7-242 7-242 29-138 8-253	Springs, Winter Quarters Area WO1-39 WO2-15 WO3-86 WO3-41 WO3-43 WO4-12	Springs, Existing Permit Area S19-2 S14-4 S16-3 S22-1 S22-5 S26-13 S34-12 S36-12	Fault Related Systems S17-2 S17-2 Green Canyon Spring Alpine Welf G-37	90yilis wire bischings formation of the Color of the Colo	Fixed by 3.07D MS-WME1-XC85.5 (Red Drip 3-07D) MS-WME1-XC85.5 (Red Drip 3-07D) MS-LL-TG_XC27 (Red Drip 3-08D)

M1-WM-E2-XC44	5/8/1996					i	0.28		
Skyline Mine Fauti inflowe 14LHGE1CSS Root 14LHGE1CSS Floor 14LHGE1CS7 Rib Water 6LTGE1CS9 M1SSM E1 C102 M1SSM E1 C102 14LEXCS9 14LHGE1CS3 RD	3/22/1999 3/22/1999 4/12/1999 12/17/1998 12/15/1999 3/22/1999	-132.28 -125.52 -125.52 -126.52	-17.91 -17.75 -17.75 -18.09 -18.03	+20.25 +18.9 +18.6 +20.6 +14.3	-10.3 -9.9 -9.8 -10.6 -10.7	10.85 9.63 6.91 19.05 17.25 17.66	0.11 0.11 0.02 0.06 0.12 0.02	13300 14400 16700 8000 11000 9500 9200	
WME2C73 HD 14LHGE1C35 EEKC22 West Submains 16LKC12 14LE1KC36 9LE3KC40 Borehole 9LE3KC40 Borehole 8LE3KC32 Borehole 8LE3KC32 Borehole 8LE3KC32 Borehole 16LEXC32 Borehole 16LE3KC32 Borehole 16LEXC32 Borehole 16LE3KC32 Fault 11L Headgate E1 KC32 11L Headgate K5 KC39 Fault 11L Headgate K5 KC39 Fault 11L Headgate K5 KC39 11L Headgate K564 11L Headgate K564 11L Headgate K564 11L Headgate K564 11L Headgate K564	3722/1998 9722/2000 9722/2000 4/19/2001 4/19/2001 4/19/2001 4/10/2002 4/10/200		-18.02 -17.84 -17.54 -17.85 -17.72		605 605 605 605 605 605 605 605 605 605	12.98 21.15 16.02 18.65 23.53 23.96 23.16 23.16 11.11 17.36 17.36 17.36 17.36 17.36	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	11500 7400 9250 8500 7256 6250 6000 12600 12600 12100 5900 5900 12,750 12,750	
11 Left Tailgate Bleader Roof Drip 11 Left Tailgate Bleeder Roof Drip 12 Left A Boretnie #2 of 5					-10.8 -10.7 -10.8	29.12 26.15 10.97 8.23	0.69 0.71 0.13 0.15		
9L. Borekrole XC59 9H. Horizontal Borekrole 9L. Horizontal Borekrole 9L. Horizontal Borekrole 9L. Horizontal Borekrole 9L. Horizontal Borekrole 9L. Horizontal Borekrole	4/10/2002 7/2/2002 8/15/2002 8/28/2002 9/23/2002	-130.45 -129.98 -129.16	-17.56 -17.53 -17.6		-10.4 -10.1	16.91 15.6	0.16 0.17 0.86 0.8 0.24 0.3	9300	
East Submains E1 XCS Fault East Submains E1 XCS Fault	4/10/2002 8/1/2002 8/15/2002 8/28/2002 9/23/2002 12/13/2003	-130.6 -130.26 -130.21	-17.62 -17.76 -17.43		-10.7 -10 -10.7 -10.4	15.17 6.28 16.73 14.88	0.01 0.09 0.08 0.07 0.17 0.11	10200	
10L Sump 10L Sump 10L Sump (alternate) 10L Sump 10L Sump (alternate) 10L Sump (alternate)	7/2/2002 7/16/2002 8/1/2002 8/1/2002 8/2/2002 9/1/3/2002 9/2/3/2002	-128.03 -127.81 -128.65 -128.64	-17.26 -17.24 -17.33 -17.55	·	10.4	24.2	1.31 1.16 1.16 1.17 1.18 1.18 1.38	8300	
Mino Downtaring Wells  Downtaring Wells  Downtaring Wells  Downtaring Wells	9252001 9252001 10:32:001 10:32:001 5:24:2002 6:42:2002 6:42:2002 6:42:2002 6:42:2002 6:42:2002 6:42:2002 10:14:2002 10:14:2002 10:17:2002 10:17:2002	-128.4 -128.41 -129 -127.91 -127.96	-17.4 -17.5 -17.8 -17.3 -17.15		8 8 1. 8 1.	30.4 30.42	0.2 0.2 0.2 0.2 0.0 0.0 0.0 0.0 0.0 0.0	, ·	
JC-1 JC-1 JC-1 (pipe outlet @ Huntington Ck) JC-1 JC-1 JC-1 JC-1	10/29/2002 12/5/2002 12/20/2002 1/14/2002 1/31/2002 2/15/2002 2/15/2002				<del>.</del>	27.58	2.06 1.87 1.94 1.83 1.77 1.8 Pending		
Electric Lake Upper Electric Lake Upper Electric Lake Upper Electric Lake (with coal) E. Lake-1 Mid Lake E. Lake-2 North End North End Strallow Elect. North End Strallow Elect. North End Deep Elect. South End Shallow Elect. South End Shallow Elect.	926/2001 9728/2001 5724/2002 771 1/2002 771 1/2002 771 1/2002 771 1/2002	-119.19 -120.36	-16.07 -15.92		æ. 	72.44 82.44	12.6 7.67 8.55 8.66 8.66	modern	
South End Deep Elect. Electric Lake at outlief EL-1 EL-8-5 EL-C-55 'Like's analytical error, campine arealyzed using teason.	7/11/2002 9/26/2001 9/25/2001 10/2/2001 10/2/2001	-110 -119:2 -109 -109	-14.43 -16.1 -14.8 -14.8	equent resampilin	-8.3 -9.2 -9.2	72.4	8.89 13		

Table 3 Recent groundwater discharge temperature data from selected locations at the Skyline Mine

10.75	٠.		0	-	57	ATT IN		$\Lambda$	1	-	7
	1	C	أأسأ		1	٤	1	mi	ě	-	

	Date	Temp °C	Carrie V Saka
Fault Inflows		•	Band associated in Mark to the America Mas
10 Left Sump	7/02/02	13.2	DIV OF OIL GAS & MINING
(measured several hundred	7/16/02	13.3	
feet from discharge location)	8/15/02	13.5	
	8/28/02	13.1	
	9/23/02	13.0	
	9/28/02	13.2	
	Average:	13.2	
East Submains E1 XC5	4/10/02	15.1	
	8/15/02	15.2	
	8/28/02	15.2	
	9/23/02	15.2	
	Average:	15.2	
Diagonal Fault	4/10/02	15.9	
Č	Average:	15.9	
Boreholes Intercepting Fau	lt (in mine)		
9 Left Horizontal Borehole	, ,	9.5	
	7/02/02	9.7	
	8/15/02	10.3	
	8/28/02	10.2	
	9/23/02	9.4	
	9/28/02	9.3	
	Average:	9.7	
Mine Dewatering Wells			
JC-1	9/26/01	14.7	
	7/16/02	14.4	
	8/01/02	14.4	
	9/13/02	14.2	
	9/24/02	13.9	
	9/28/02	14.0	
	Average:	14.3	
In-Mine Roof-Drip Water	•		
11 Left HG E1 XC62 R.D.	4/10/02	8.9	
	Average:	8.9	

Table 4 Estimated groundwater circulation depths based on discharge temperatures.

Location	Average temp °C	Deviation from average mine temp. (8.9 °C) <sup>1</sup>	Calculated circulation depth below local mine level <sup>2</sup>
Fault Inflows, boreholes, and mi	ne dewatering wells		
Measured at discharge location			
East Submains E1 XC5	15.2		
Diagonal Fault	15.9		
	Average: 15.6	6.7	291 meters (955 feet)
Measured away from discharge le	ocation		
10 Left Sump	13.2		
	Average: 13.2	4.3	187 meters (614 feet)
Mine dewatering well			
JC-1	14.3		
	Average: 14.3	5.4	235 meters (771 feet)
Horizontal boreholes			
9 Left horizontal borehole	9.7		
, 2010	Average: 9.7	0.8	35 meters (115 feet)
In-Mine Roof-Drip Water			
11 Left HG E1 XC62 Roof	Drip 8.9		
11 201110 21 11002 11001	Average: 8.9	0.0	<b></b>

Based on the discharge temperature of groundwater from a sandstone paleochannel immediately above the mine roof in the vicinity of the fault inflows (11 Left HG E1 XC62 Roof Drip). This is very old groundwater (approximately 5,900 years) that has equilibrated with the rocks surrounding the mine openings. Other nearby roof drip waters have similar discharge temperatures.

7007 7 0 7 1

<sup>&</sup>lt;sup>2</sup>Based on an average local geothermal gradient of approximately 23 °C per kilometer (written communication, Dr. David S. Chapman, University of Utah, 2002).

Table 5 Solute chemical compositions of fault-inflow groundwater and Electric Lake water.

	Date	рΗ	DO	Cond	Ca2+	Mg <sup>2+</sup>	Na⁺	K <sup>+</sup>	Fe (d)	HCO <sub>3</sub>	CO <sub>3</sub> <sup>2-</sup>	SO <sub>4</sub> 2-	Cl	$Si_{calc}$	$Si_{dolo}$	$Si_{gyp}$
		(s.u.)	(mg/l)	(µS)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)			
Electric Lake																
Upper Electric Lake	9/26/2001	8.65	7.3	282	41.95	8.55	3.68	1.02	<0.1	163	<0.1	8.94	10.13	0.92	1.42	<del>-</del> 2.73
North End Shallow Elect.	7/11/2002	8.91	7.64	260	35.03	7.00	3.92	0.86	<0.1	144.6	<0.1	5.91	4.9	1.07	1.74	-2.98
North End Deep Elect.	7/11/2002	8.94	7.52	274	36.8	7.37	3.85	0.9	<0.1	153.3	<0.1	6.07	4.91	1.10	1.78	-2.95
South End Shallow Elect.	7/11/2002	8.86	7.36	263	35.91	7.06	3.92	0.86	<0.1	153.2	<0.1	5.92	5.03	1.05	1.71	-2.97
South End Deep Elect.	7/11/2002	7.99	6.24	284	38.36	6.84	4.11	0.85	<0.1	140.6	<0.1	5.71	5.28	0.09	-0.47	-2.91
North End Shallow Elect.	7/26/2002	8.71	6.76	223	35.38	7.98	4.07	1.42	<0.1	142.5	<0.1	6.65	7.3	0.87	1.38	-2.92
South End Shallow Elect.	7/26/2002	8.78	6.38	222	31.91	7.37	4.93	1.53	<0.1	139.8	<0.1	6.47	7.73	0.90	1.45	-2.97
Average		8.69	7.03	258	36.5	7.5	4.1	1.1	<0.1	148	<0.1	6.5	6.5	0.86	1.29	-2.92
In-Mine Fault-related Inflow																
East Submains E1 XC5 Fault	9/28/2002	7.58	0.45	349	36	15	8	3	<0.1	205	<5	6	1	-0.12	-0.40	-2.97
10L E1 Sump	9/28/2002	7.59	0.78	392	46	16	4	2	<0.1	222	<5	9	2	-0.01	-0.29	-2.70
JC-1	9/28/2002	7.64	0.56	379	79	38	7	2	<0.1	222	<5	9	2	0.25	0.36	-2.57
Average		7.60	0.60	373	53.7	23.0	6.3	2.3	<0.1	216	<5	8.0	1.7	0.04	-0.11	-2.74

Table 6 Magnitude of potential modern water component in mine dewatering well JC-1 based in tritium content.

			ASSUMPTIONS	
		Modern water at 9.81 TU (average Electric Lake)	Modern water at 17.58 TU (average springs and streams)	Modern water at 13.70 TU (avg. springs, streams, E. Lake)
	JC-1 tritium content			
Date	(TU)	Modern water fraction	Modern water fraction	Modern water fraction
26-Sep-2001	0.24	0.024	0.014	0.018
24-May-2002	1.02	0.104	0.058	0.074
4-Jun-2002	0.96	0.098	0.055	0.070
19-Jun-2002	1.11	0.113	0.063	0.081
28-Jun-2002	1.18	0.120	0.067	0.086
16-Jul-2002	1.09	0.111	0.062	0.080
1-Aug-2002	1.22	0.124	0.069	0.089

Table 7 Average tritium contents of surface water, shallow groundwater, and well JC-1.

	Tritium (TU)	
	Tritiani (10)	
Electric Lake		•
Electric Lake 26 Sep 01	12.60	INCORPORATED
Electric Lake 24 May 02 average	8.10	
Electric Lake 11 Jul 02 average	8.73	Bernet William
Electric Lake average	9.81	
		DIV OF OIL GAS & MINING
Springs and Creeks		
S13-2 (1995)	18.80	
S15-3 (1995)	17.10	
S22-11 (1995)	21.60	
S34-12 (1995)	20.40	
S36-12 (1995)	18.10	
2-413 average (1997-1998)	14.95	
7-242 (1997)	10.50	
29-138 (1997)	13.45	
8-253 average (1997-1998)	29.85	
32-279 average (1997-1998)	14.50	
MST-3 average (1997-1998)	11.70	
CS-9, Eccles Creek (1995)	21.80	
CS-10, upper Huntington Creek (1995)	15.80	
Average	17.58	
0		
Springs, Creeks, and Electric Lak		
Average	13.70	
Mine Dewatering Well JC-1		
JC-1 (26 Sep 2001)	0.17	
JC-1 (26 Sep 2001) JC-1 (24 May 2002)	1.02	
JC-1 (4 Jun 2002)	0.96	
JC-1 (19 Jun 2002)	1.11	
JC-1 (28 Jun 2002)	1.18	
JC-1 (16 Jul 2002)	1.00	
IC 1 (1 A 2002)	1.00	

1.22

JC-1 (1 Aug 2002)

Table 2 Isotopic compositions of groundwaters and surface waters in the Skyline Mine area.

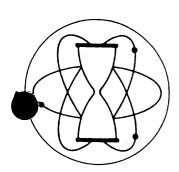
Site	Date	δ <sup>2</sup> Η (‰)	δ <sup>18</sup> O (‰)	δ <sup>34</sup> S (‰)	δ <sup>13</sup> C (‰)	<sup>14</sup> C (pmC)	Tritium (TU)	Mean residence time
Creeks								
CS-9	10/17/1995						21.8	
CS-10	5/22/1996						15.8	
C-1	Oct-97	-124.37	-16.28				13.6	
C-1	Jul-98	-124.94	-16.31					13
C-2	Oct-97	-16.06	-123.8					INCORPORATED
C-2	Jul-98	-119.38	-15.76					JIMILD
C-3	Oct-97	-16.73	-127.22					The state of the state of
C-3	Jul-98	-124.99	-16.52					6-0 0 1 20.Z
C-4	Oct-97	-16.17						
C-4			-124.05					DIV OF OIL GAS & MINING
C-5	Jul-98	-124.32	-16.19					OF GERY WINNING
C-5	Oct-97	-16.47	-124.13					
C-9	Jul-98	-122.77	-16.12					
Springs, Flat Canyon Tract								
2-413	10/8/1997	-128.79	-17.31		-13.8	95.71	14.9	modern
2-413	7/22/1998	-129.94	-16.98		-12.4	91.68	15	modern
7-242	10/9/1997	-120.81	-16.28		-13.1	73.52	10.5	modern
7-242	7/1/1998	-122.86	-16.46		40.0	00		_
29-138	10/8/1997	-127.06	-16.85		-12.3	88.58	12.9	modern
29-138 8-253	7/21/1998	-125.02	-16.25		-13.5	90.96	14	modern
8-253	10/9/1997 7/21/1998	-129.7 -133.51	-17.31 -17.32		-16.0 -16.1	84.39 79.06	29.7 30	modern
32-279	10/9/1997	-127.42	-17.32 -17.23		-10.1	68.62	30 14	modern
32-279	7/21/1998	-125.03	-16.86		-12.5	71.67	15	modern modern
MST-3	9/11/1997	-127.6	-17.03		12.0	71.07	13.1	modern
MST-3	7/21/1998	-125.61	-16.25		-12.1	71.35	10.3	modern
MSS-1	10/1/1997	-128.7	-17.08		,			deiii
MST-1	10/1/1997	-125.87	-16.71					
MST-1	7/1/1998	-124.13	-16.24					
MST-2	10/1/1997	-128.82	-17.18					
MST-2	7/1/1998	-125.33	-16.36					
19-175	10/1/1997	-131.33	-17.55					
19-175	7/1/1998	-130.21	-17.11					
21-222 21-222	10/1/1997	-126.24	-16.91					
28-110	7/1/1998 10/1/1997	-128.24 -127.17	-16.82 -16.92					
28-110	7/1/1998	-128.78	-17.13					
29-133	10/1/1997	-128.04	-17.13					
29-133	7/1/1998	-124.32	-16.53					
3-290	10/1/1997	-130.31	-17.25					
3-290	7/1/1998	-128.56	-16.82					
31-181	10/1/1997	-126.66	-16.99					
32-183	10/1/1997	-127.65	-16.88					
32-183	7/1/1998	-125.25	-16.46					
32-276	10/1/1997	-125.8	-16.99					
32-277	10/1/1997	-124.03	-16.84					
32-277 33-368	7/1/1998	-127.41	-16.61					
33-268 33-271	10/1/1997 10/1/1997	-129.24 -128.49	-17.31 -17.18					
33-271 33-271	7/1/1998	-128. <del>49</del> -125.19	-17.18 -16.53					
33-273	10/1/1997	-125.19	-10.53					
33-273	7/1/1998	-126.51	-17.48					
4-173	10/1/1997	-131.37	-17.53					
4-173	7/1/1998	-125.84						
4-429	10/1/1997							
5-231	10/1/1997	-124.35						
5-231	7/1/1998	-126.69						
5-238	10/1/1997	-123.75	-16.75					
Springs, Winter Quarters Area WQ1-39	6/6/1996			+12.1	-15.0		12	
WQ2-15	6/5/1996			+8.5	-12.45		12	
WQ3-6	6/5/1996			+5.7	-12.45	87.36	13.9	modern
VVCJ3-0						07.30	10.0	ORACELO
WQ3-0 WQ3-26								
	6/5/1996 6/6/1996			+8.1 +13.5	-14.6 -12.0	107.14 100.40	11.1 18.4	modern modern

Site	Date	δ <sup>2</sup> Η (‰)	δ <sup>18</sup> Ο (‰)	δ <sup>34</sup> S (‰)	δ <sup>13</sup> C (‰)	<sup>14</sup> C (pmC)	Tritium (TU)	Mean residence time
WQ4-12	6/5/1996			+11.3	-13.7	82.78	10.6	modern 💆
Springs, Existing Permit Area								유 등
S13-2	10/17/1995			+10.4	-12.0	80.12	18.8	modern O
S14-4	10/17/1995			+14.75	-13.1			modern e
S15-3	10/18/1995			+16.5	-13.2	62.40	17.1	modern 👩 😂
S22-11	10/18/1995			+5.1	-13.3	75.49	21.6	modern of the modern
S22-5	10/18/1995			+10.6	-12.1			~ f:3
S26-13	10/17/1995			+8.9				modern \( \frac{\xi}{2} \)
S34-12	10/18/1995			+9.1	-13.0	78.26	20.4	modern 📈 🍋
S35-8 S36-12	10/18/1995 10/17/1995			+12.9 +10.6	-10.8 -13.3	85.16	18.1	modern G
							-	
Fault Related Systems								
S17-2	10/17/1995			-1.5	-10.5	39.56	1.61	3,000 mixed w/modern
S17-2	5/22/1996			0.7			1.73	
Green Canyon Spring	7/23/1996			-0.7	-12.5	18.29	0.21	9,500
Alpine Well G-37	7/23/1996			+12.7	-14.7	7.06	-0.02	17,000
	7/23/1996			+19.45	-12.3	20.99	0.05	8,500
Skyline Mine Blackhawk Formation   1-01D	perched Gro 10/6/1993	undwater	Systems	6.7	-8.4			
1-02D	10/6/1993			6.2	-0. <del>4</del> -2.1			
1-05D	5/8/1996			0.2	-2.1		0.3	
1-11D	10/6/1993			17.2	-10.3		0.3	
1-12D	10/6/1993			16.6	-9.4			
1-14D	5/8/1996			13.9	-8.7	21.4	0	
1-01S	10/6/1993			10.0	-13.8	5.6	0	
1-02S	10/6/1993			19.3	-11.1	0.0	Ü	
3-01D	10/6/1993			8.9	-8.6			
3-04D	10/6/1993				-9.5			
3-05D	10/6/1993				-1.5			
3-06D	10/6/1993				-7.3			
3-07D	10/6/1993			19.4	-10.8	14.1	6.7	
3-07D	5/8/1996						0.1	
3-08D	5/8/1996			14.8	-10.9	41.5	0.3	
3-02S	10/6/1993			16.8	-10			
Roof Drip 1-03D	10/6/1993			+16.35	-10.7	15.4	5.6*	10,500
Roof Drip 1-05D	5/8/1996						0.28	
M1-9L-E1-XC31.5 (Roof Drip 1-14D)	5/8/1996			+13.9	-8.7	21.36	0.16	7,500
M1-9L-E2-XC23.5 (Roof Drip 1-15D)	5/8/1996			+15.5	-10.3	28.65	0.16	5,500
Floor Water 1-01S	10/6/1993				-13.8	5.6	0	18,500
Roof Drip 3-07D	10/6/1993			+19.4	-10.8	14.1	6.7*	10,500
M3-WM-E1-XC85.5 (Roof Drip 3-07D)							0.12	·
M3-1L-TG_XC27 (Roof Drip 3-08D) M1-WM-E2-XC44	5/8/1996			+14.8	-10.9	41.5	0.26	2,500
IVI 1-VVIVI-E2-AC44	5/8/1996						0.28	
Skyline Mine Fault Inflows 14LHGE1C35 Roof	3/22/1999	-133.77	-17.91	+20.25	-10.3	10.05	0.04	12 200
14LHGE1C35 Floor	3/22/1999	-130.88	-17.91	+20.25	-10.3 -9.7	10.85 9.63	-0.01 0.11	13,300 14,400
14LHGE1C37 Rib Water	4/12/1999	-132.28	-17.75	+18.6	-9.9	6.91	0.02	16,700
5LTGE1C39	12/17/1998		-17.75	+20.6	-9.8	19.05	-0.06	8,000
M1SSM E1 C102	12/17/1998			+14.3	-10.6	13.26	0.06	11,000
16LE2XC11.5	12/15/1999		-18.09	14.0	-10.7	17.25	0.12	9,500
14LE1XC36	12/15/1999		-18.03		-10.1	17.66	0.02	9,200
14LHGE1C23 RD	3/22/1999	-130.95	-17.45		10.1	11.00	0.02	3,200
WME2C73 RD	3/22/1999	-136.7	-18.02					
14LHGE1C35	9/22/2000				-10.2	12.98	-0.02	11,500
E6XC22 West Submains	9/22/2000				-10.3	21.15	0.00	7,400
16LXC12	4/18/2001				-9.9	16.02	-0.02	9,250
14LE1XC36	4/18/2001				-10.3	18.65	0.12	8,500
9LE3XC40 Borehole	4/19/2001				-11.2	23.53	0.06	7,250
Diagonal Submains E3XC12	4/19/2001				-10.3	23.98	0.05	6,250
8LE3XC62 Borehole	4/18/2001				-11.9	29.11	0.78	6,000
8L Bleeder XC51 Borehole	4/18/2001				-12.3	13.66	0.51	12,500
8LE2XC62 Borehole (uncased)	4/18/2001				-11.9	8.15	0.06	16,500
Diagonal Fault	4/10/2002				-10.3	11.91	0.01	12,100
11L Headgate E1 XC62	4/10/2002				-10.5	25.57	0.31	5,900
East Submains E3 XC14 Fault	4/10/2002				-10.3	17.36	0.88	9,000
11L Headgate E1 XC39 Fault	4/10/2002				-10.9	2.29	0.01	25,800

Site	Date	δ <sup>2</sup> Η (‰)	δ <sup>18</sup> O (‰)	δ <sup>34</sup> S (‰)	δ <sup>13</sup> C (‰)	<sup>14</sup> C (pmC)	Tritium (TU)	Mean residence time
11L Headgate XC54	4/25/2002				-10.1	7.26	0.06	16,300
9L Borehole XC59	4/10/2002				-10.4	16.91	0.16	9,300
9L Horizontal Borehole	7/2/2002				-10.1	15.60	0.17	9,300 9,700 DIV 9,700 O
9L Horizontal Borehole	8/15/2002						0.86	유
9L Horizontal Borehole	8/28/2002						0.83	
East Submains E1 XC5 Fault	4/10/2002				-10.7	15.17	0.01	10,200
East Submains E1 XC5 Fault	8/1/2002						0.09	်ဂ ဧ
East Submains E1 XC5 Fault	8/15/2002						0.08	GAS
East Submains E1 XC5 Fault	8/28/2002						0.07	0; t:
10L Sump	7/2/2002				-10.4	24.2	1.31	6,300
10L Sump	7/16/2002						1.19	
10L Sump (alternate)	8/1/2002						1.16	6,300 E MINING
10L Sump	8/15/2002						1.18	5
10L Sump	8/28/2002						1.17	<b>54</b> *
Mine Dewatering Wells								
JC-1	9/25/2001	-128.4	-17.4		-11.80	30.4	0.2	
JC-1	9/26/2001	-128.41	-17.5		-11.8	30.42	0.24	4,600
JC-1	10/3/2001	-129	-17.8				0.2	
JC-1	5/24/2002						1.04	
JC-1	5/24/2002						1.00	
JC-1	6/4/2002						0.96	
JC-1	6/19/2002						1.11	
JC-1	6/28/2002						1.18	
JC-1	7/16/2002						1.09	
JC-1	8/1/2002						1.22	
Electric Lake								
Upper Electric Lake	9/26/2001	-119.19	-16.07		-8.3	72.44	12.6	modern
Upper Electric Lake (with coal)	9/26/2001	-120.36	-15.92		-8.7	82.44		modern
E. Lake-1 Mid Lake	5/24/2002						7.67	
E.Lake-2 North End	5/24/2002						8.52	
North End Shallow Elect.	7/11/2002						8.66	
North End Shallow Elect.	7/26/2002							
North End Deep Elect.	7/11/2002						8.66	
South End Shallow Elect.	7/11/2002						8.69	
South End Shallow Elect.	7/26/2002							
South End Deep Elect.	7/11/2002						8.89	
Electric Lake at outlet	9/26/2001	-110	-14.43					
EL-1	9/25/2001	-119.2	-16.1		-8.3	72.4	13	
EL-B-5	10/2/2001	-109	-14.8					
EL-C-55	10/2/2001	-109	-14.8		-9.2	82.2	12	

<sup>\*</sup> Likely analytical error, samples analyzed using less accurate direct counting technique, verified on subsequent resampling at 3-07D





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INCORPORATED

CCC 072002

DIV OF OIL GAS & MINING

RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No. GX-22116

Date Received:

07/29/96

Your Reference: letter of 07/26/96

Date Reported:

08/14/96

Submitted by: Mr. Kelly Payne

Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name: Alpine Well

groundwater precipitate

AGE =

21,290 +3,010/-2,180 C-14 years BP (C-13 corrected). (7.06 + - 2.21) % of the modern (1950) C-14 activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover. carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion of the same evolved gas.

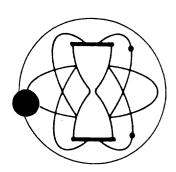
Comment:

Very small sample; approximately 0.38 grams C.

 $\delta^{13}C_{PDB} = -14.7$  %

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm 1\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.





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#### RADIOCARBON AGE DETERMINATION

#### REPORT OF ANALYTICAL WORK

Our Sample No. GX - 23716

Date Received: 12/18/97

Your Reference: letter of 12/11/97

Date Reported: 01/06/98

Submitted by: M1

Mr. Mark Nicholls Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name: WEST RIDGE: Church Well 09/23/97

AGE =

3,670 +/- 280 C-14 years BP (C-13 corrected). (63.33 +/- 2.18) % of the modern (1950) C-14 activity.

Description:

Sample of groundwater precipitate.

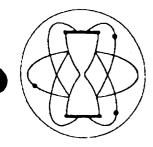
Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion of the same evolved gas.

Comment:

$$\delta^{13}C_{PDB} = -15.6$$
 %

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm 1\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.



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# TELEFAX COVER SHEET FROM TELEFAX NUMBER (617) 661-0148

NCORPORATED

DIV OF OIL GAS & MINING

DATE: 11.06.2000

TO: Alan L. Mayo

TELEFAX NUMBER: 801 785-2387

FROM: Alex Cherkinsky

NUMBER OF PAGES INCLUDING COVER PAGE: 1

**MESSAGE:** 

Dear Alan,

We have analyzed 3 of your 4 samples. Here are the results.

GX#	Your sample name	$\delta^{13}$ C, per mil	pmC*
27346	14L H6 E1 C35 (lab 1328)	-10.2	12.98±1.21
27347	E6 XC 22 West Submains (lab 1325)	-10.3	21.15±1.21
27349	14L E2 XC 102 (lab 1326)	-10.2	24.45±1.90

<sup>\*</sup> pmC – percent of modern carbon

The sample 14L Setup (lab 1327) (our number GX-27348) was too small to analyze by conventional method and could be done by AMS technique only for the price \$550 per sample.

Please let me know if you wish to date this sample by AMS.

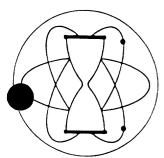
Please note our price for conventional method has been changed on October 1, 2000 and is \$300 per sample now.

Best regards,

Dr. Alexander Cherkinsky

Radiocarbon Lab Manager

SPECIALISTS IN GEOCHRONOLOGY & ISOTOPE GEOLOGY



CEC 0 / 2012

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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-25492-PRI

Date Received:

03/24/99

Your Reference:

Skyline Mine

Date Reported:

03/30/99

Submitted by:

Mr. Erik C. Petersen Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

14L HG E1 C35 Roof 22 Mar 99

AGE =

 $17,840 \pm 810$  <sup>14</sup>C years BP (<sup>13</sup>C corrected).

 $(10.85 \pm 1.09)$  % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

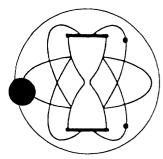
<sup>13</sup>C analysis was made on a small portion of the same evolved gas.

Comments:

 $\delta^{13}C_{PDB} =$ 

- 10.3 %

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-25491-PRI

Date Received:

03/24/99

Your Reference:

Skyline Mine

Date Reported:

03/30/99

Submitted by:

Mr. Erik C. Petersen Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

14L HG E1 C35 Floor 22 Mar 99

AGE =

 $18,800 \pm 1,090 \, ^{14}\text{C}$  years BP (13C corrected).

 $(9.63 \pm 1.30)$  % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

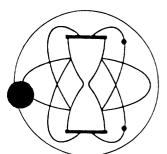
<sup>13</sup>C analysis was made on a small portion of the same evolved gas.

Comments:

 $\delta^{13}C_{PDB} =$ 

- 9.7 %

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-25316

Date Received:

01/15/99

Your Reference:

Skyline Mine

Date Reported:

03/24/99

Submitted by:

Mr. Travis L. Jensen Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

5LTG E1 C39 12/17/98

AGE =

13,320  $\pm$  630 <sup>14</sup>C years BP (<sup>13</sup>C corrected). (19.05  $\pm$  1.49) % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed. under vacuum, to recover carbon dioxide from the barium carbonates for the analysis. <sup>13</sup>C analysis was made on a small portion of the same evolved gas.

Comments:

 $\delta^{13}C_{PDB} =$ 

- 9.8 %.

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



INCORPORATED 711 Concord Avenue New Address Cambridge, MA 02138 Telephone/Telefax Numbers remain the same

# KRUEGER ENTERPRISES. INC. DIV OF OIL GAS & MINING

GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

#### RADIOCARBON AGE DETERMINATION

#### REPORT OF ANALYTICAL WORK

Our Sample No. GX - 19553

Date Received:

10/12/93

Your Reference: letter of 10/04/93

Date Reported:

12/28/93

Submitted by:

Mr. Erik Petersen Mayo and Associates Post Office Box 1960 Orem, Utah 84059

Sample Name: #1 WM6 C94 1-03 D

groundwater precipitate

15,015 + - 810 C-14 years BP (C-13 corrected).AGE =

(15.4 + / - 1.6) % of the modern (1950) C-14 activity.

Description: Sample of groundwater precipitate.

Pretreatment: The salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the carbonates for the analysis. C-13 analysis was made on a small portion of the same evolved gas.

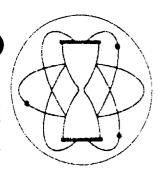
Comment:

Relatively small sample.

 $\delta^{13}C_{PDE} = ^{-10.7}$ 

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$  C. The error stated is  $\pm 1\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.

### INCORPORATED



# GEOCHRON LABORATORIES

DEC 0 2 26.02

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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-27953

Date Received:

05/09/2001

Your Reference:

Skyline Mines

Date Reported:

05/22/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

14L E1 XC36 18 April 2001

AGE =

 $18.65 \pm 2.35$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion—f the same evolved gas.

Comments:

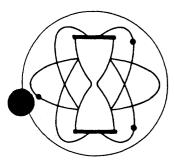
Extremely small sample yielding only 0.25 grams of carbon.

 $\delta^{13}C_{PDB} =$ 

-10.3 %c

Notes:

This date is based upon the Libby half life (5570 years) for  ${}^{14}$ C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-24405

Date Received:

08/07/98

Your Reference:

Canyon Fuel Company

Date Reported:

08/26/98

Submitted by:

Mr. Kelly Payne Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

Skyline Mines:

MST-3 07/21/98

AGE =

2,710  $\pm$  400 <sup>14</sup>C years BP (<sup>13</sup>C corrected).

 $(71.35 \pm 3.53)$  % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

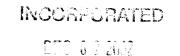
13C analysis was made on a small portion of the same evolved gas.

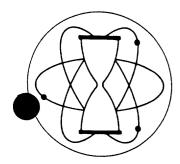
Comments:

 $\delta^{13}C_{PDB} =$ 

-12.1 ‰

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-24409

Date Received:

08/07/98

Your Reference:

Canyon Fuel Company

Date Reported:

08/26/98

Submitted by:

Mr. Kelly Payne Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

Skyline Mines:

29-138 07/21/98

AGE =

 $760 \pm 130$  <sup>14</sup>C years BP (<sup>13</sup>C corrected).

 $(90.96 \pm 1.47)$  % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

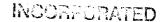
<sup>13</sup>C analysis was made on a small portion of the same evolved gas.

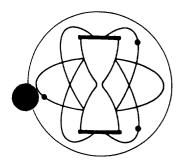
Comments:

 $\delta^{13}C_{PDB} =$ 

-13.5 ‰

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-24407

Date Received:

08/07/98

Your Reference:

Canyon Fuel Company

Date Reported:

08/26/98

Submitted by:

Mr. Kelly Payne Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

Skyline Mines:

8-253 07/21/98

AGE =

1,890  $\pm$  290 <sup>14</sup>C years BP (<sup>13</sup>C corrected).

 $(79.06 \pm 2.81)$  % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

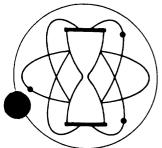
13C analysis was made on a small portion of the same evolved gas.

Comments:

 $\delta^{13}C_{PDB} =$ 

-16.1 ‰

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-24406

Date Received:

08/07/98

Your Reference:

Canyon Fuel Company

Date Reported:

08/26/98

Submitted by:

Mr. Kelly Payne Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

Skyline Mines:

2-413 07/22/98

AGE =

 $700 \pm 150$  <sup>14</sup>C years BP (<sup>13</sup>C corrected).

 $(91.68 \pm 1.74)$  % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

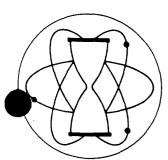
<sup>13</sup>C analysis was made on a small portion of the same evolved gas.

Comments:

 $\delta^{13}C_{PDB} =$ 

-12.4 ‰

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-24408

Date Received:

08/07/98

Your Reference:

Canyon Fuel Company

Date Reported:

08/26/98

Submitted by:

Mr. Kelly Payne Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

Skyline Mines:

32-279 07/21/98

AGE =

 $2,675 \pm 215$  <sup>14</sup>C years BP ( $^{13}$ C corrected).

 $(71.67 \pm 1.93)$  % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

13C analysis was made on a small portion of the same evolved gas.

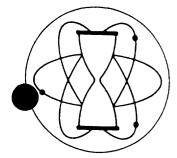
Comments:

 $\delta^{13}C_{PDB} =$ 

-12.5 ‰

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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#### RADIOCARBON AGE DETERMINATION

#### REPORT OF ANALYTICAL WORK

Our Sample No. GX - 23720

Date Received: 12/18/97

Your Reference: letter of 12/11/97

Date Reported: 01/06/98

Submitted by: Mr. Mark Nicholls

Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name: WEST RIDGE: 32-279 10/09/97 West Tract

AGE = 3,025 +/- 115 C-14 years BP (C-13 corrected).

(68.62 + / - 1.00) % of the modern (1950) C-14 activity.

Description: Sample of groundwater precipitate.

Pretreatment: The barium salt precipitate was rapidly vacuum filtered

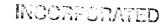
and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion

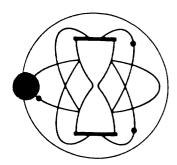
of the same evolved gas.

Comment:

 $\delta^{13}C_{PDB} = -12.3$  %

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$  C. The error stated is  $\pm 1\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.





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DIV OF CIL GAS & MINING

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#### RADIOCARBON AGE DETERMINATION

#### REPORT OF ANALYTICAL WORK

Our Sample No. GX - 23719

Date Received:

12/18/97

Your Reference: letter of 12/11/97

Date Reported:

01/06/98

Submitted by:

Mr. Mark Nicholls Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name: WEST RIDGE: 8-253 10/09/97 West Tract

AGE = 1,360 +/- 200 C-14 years BP (C-13 corrected).

(84.39 + / - 2.14) % of the modern (1950) C-14 activity.

Description: Sample of groundwater precipitate.

Pretreatment: The barium salt precipitate was rapidly vacuum filtered

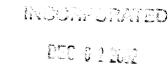
and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion

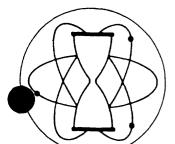
of the same evolved gas.

Comment:

$$\delta^{13}C_{PDB} = -16.0$$
 %

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm 1\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.





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#### RADIOCARBON AGE DETERMINATION

#### REPORT OF ANALYTICAL WORK

Our Sample No. GX - 23715

12/18/97 Date Received:

Your Reference: letter of 12/11/97

01/06/98 Date Reported:

Mr. Mark Nicholls Submitted by:

Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name: WEST RIDGE: 7-242 10/09/97 West Tract

AGE = 2,470 +/- 150 C-14 years BP (C-13 corrected).

(73.52 + - 1.39) % of the modern (1950) C-14 activity.

Description: Sample of groundwater precipitate.

Pretreatment: The barium salt precipitate was rapidly vacuum filtered

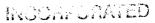
and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion

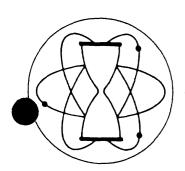
of the same evolved gas.

Comment:

$$\delta^{13}C_{PDB} = -13.1$$
 %

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$  C. The error stated is  $\pm 1\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.





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### RADIOCARBON AGE DETERMINATION

### REPORT OF ANALYTICAL WORK

Our Sample No. GX - 23717

Date Received: 12/18/97

Your Reference: letter of 12/11/97

Date Reported: 01/06/98

Submitted by: Mr. Mark Nicholls

Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name: WEST RIDGE: 29-138 10/08/97 West Tract

AGE = 975 + - 105 C - 14 years BP (C - 13 corrected).

(88.58 + / - 1.13) % of the modern (1950) C-14 activity.

Description: Sample of groundwater precipitate.

Pretreatment: The barium salt precipitate was rapidly vacuum filtered

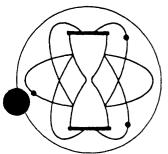
and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion

of the same evolved gas.

Comment:

 $\delta^{13}C_{PDB} = -12.3$  %

Notes: This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error stated is ±1σ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.



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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-27953

Date Received:

05/09/2001

Your Reference:

Skyline Mines

Date Reported:

05/22/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

14L E1 XC36 18 April 2001

AGE =

 $18.65 \pm 2.35$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

Comments:

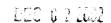
Extremely small sample yielding only 0.25 grams of carbon.

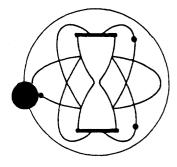
 $\delta^{13}C_{PDB} =$ 

-10.3 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-27954

Date Received:

05/09/2001

Your Reference:

Skyline Mines

Date Reported:

05/22/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

9L E3 XC40 Borehole 19 April 2001

AGE =

 $23.53 \pm 1.64$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

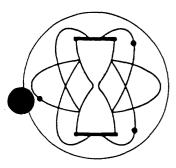
Comments:

 $\delta^{13}C_{PDB} =$ 

-11.2 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-27955

Date Received:

05/09/2001

Your Reference:

Skyline Mines

Date Reported:

05/22/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

Diagonal Submains E3 XC12 Fault 19 April 2001

AGE =

 $23.98 \pm 1.28$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

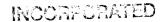
Comments:

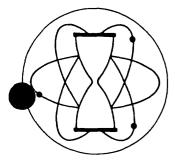
 $\delta^{13}C_{PDB} =$ 

-10.3 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-27952

Date Received:

05/09/2001

Your Reference:

Skyline Mines

Date Reported:

05/22/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic

2695 N. 600 E. Lehi, Utah 84043

Sample Name:

16L XC12 18 April 2001

AGE =

 $16.02 \pm 1.99$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

Comments:

Extremely small sample yielding only 0.3 grams of carbon.

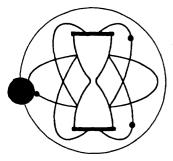
 $\delta^{13}C_{PDR} =$ 

-9.9 ‰

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-27954

Date Received:

05/09/2001

Your Reference:

Skyline Mines

Date Reported:

05/22/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

9L E3 XC40 Borehole 19 April 2001

AGE =

 $23.53 \pm 1.64$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

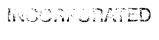
Comments:

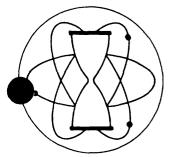
 $\delta^{13}C_{PDB} =$ 

-11.2 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-27956

Date Received:

05/09/2001

Your Reference:

Skyline Mines

Date Reported:

06/20/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

8L E3 XC62 Borehole 18 April 2001

AGE =

29.11  $\pm$  0.16 % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater.

Pretreatment:

The sample was rapidly transferred, by aspiration, to an evacuated flask and acidified to recover carbon dioxide from dissolved carbonates for the analysis. <sup>13</sup>C analysis was performed on a small portion of the same evolved gas.

The sample yielded very little carbon and analysis by accelerator mass spectrometry (AMS) was required.

Comments:

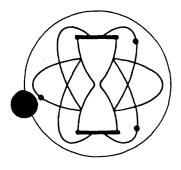
 $\delta^{13}C_{PDB} =$ 

-11.9 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-27953

Date Received:

05/09/2001

Your Reference:

Skyline Mines

Date Reported:

05/22/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

14L E1 XC36 18 April 2001

AGE =

 $18.65 \pm 2.35 \%$  of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

Comments:

Extremely small sample yielding only 0.25 grams of carbon.

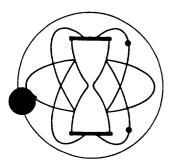
 $\delta^{13}C_{PDB} =$ 

-10.3 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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## RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-27955

Date Received:

05/09/2001

Your Reference:

Skyline Mines

Date Reported:

05/22/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E.

2695 N. 600 E. Lehi, Utah 84043

Sample Name:

Diagonal Submains E3 XC12 Fault 19 April 2001

AGE =

 $23.98 \pm 1.28 \%$  of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

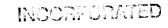
Comments:

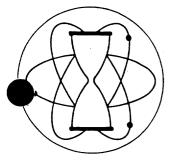
 $\delta^{13}C_{PDB} =$ 

-10.3 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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## RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-27957

Date Received:

05/09/2001

Your Reference:

Skyline Mines

Date Reported:

06/20/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E.

2695 N. 600 E. Lehi, Utah 84043

Sample Name:

8L Bleeder XC51 Borehole 18 April 2001

AGE =

13.66  $\pm$  0.11 % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater.

Pretreatment:

The sample was rapidly transferred, by aspiration, to an evacuated flask and acidified to recover carbon dioxide from dissolved carbonates for the analysis. <sup>13</sup>C analysis was performed on a small portion of the same evolved gas.

The sample yielded very little carbon and analysis by accelerator mass spectrometry

(AMS) was required.

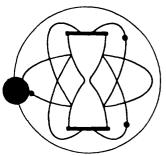
Comments:

 $\delta^{13}C_{PDB} =$ 

-12.3 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-27958

Date Received:

05/09/2001

Your Reference:

Skyline Mines

Date Reported:

06/20/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

8L E2 XC62 Borehole (uncased) 18 April 2001

AGE =

 $8.15 \pm 0.07$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater.

Pretreatment:

The sample was rapidly transferred, by aspiration, to an evacuated flask and acidified to recover carbon dioxide from dissolved carbonates for the analysis. <sup>13</sup>C analysis was performed on a small portion of the same evolved gas.

The sample yielded very little carbon and analysis by accelerator mass spectrometry

(AMS) was required.

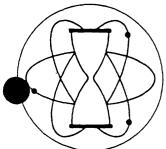
Comments:

 $\delta^{13}C_{PDB} =$ 

-11.9 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-27952

Date Received:

05/09/2001

Your Reference:

Skyline Mines

Date Reported:

05/22/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E.

Lehi, Utah 84043

Sample Name:

16L XC12 18 April 2001

AGE =

 $16.02 \pm 1.99$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

Comments:

Extremely small sample yielding only 0.3 grams of carbon.

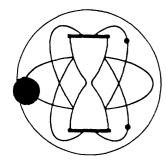
 $\delta^{13}C_{PDR} =$ 

-9.9 ‰

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-25565-PRI

Date Received:

04/14/99

Your Reference:

Willow Creek

Date Reported:

04/20/99

Submitted by:

Mr. Erik C. Petersen Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

14L HG E1 C37 Rib Water 12 APR 99

AGE =

21,460  $\pm$  1,420 <sup>14</sup>C years BP (<sup>13</sup>C corrected).

 $(6.91 \pm 1.21)$  % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

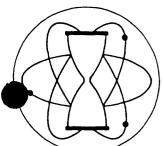
<sup>13</sup>C analysis was made on a small portion of the same evolved gas.

Comments:

 $\delta^{13}C_{PDB} =$ 

- 9.9 %

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-25491-PRI

Date Received:

03/24/99

Your Reference:

Skyline Mine

Date Reported:

03/30/99

Submitted by:

Mr. Erik C. Petersen Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

14L HG E1 C35 Floor 22 Mar 99

AGE =

18,800  $\pm$  1,090 <sup>14</sup>C years BP (<sup>13</sup>C corrected).

 $(9.63 \pm 1.30)$  % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

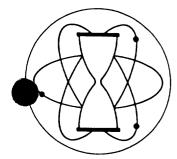
<sup>13</sup>C analysis was made on a small portion of the same evolved gas.

Comments:

 $\delta^{13}C_{PDB} =$ 

- 9.7 %

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-25492-PRI

Date Received:

03/24/99

Your Reference:

Skyline Mine

Date Reported:

03/30/99

Submitted by:

Mr. Erik C. Petersen Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

14L HG E1 C35 Roof 22 Mar 99

AGE =

 $17,840 \pm 810^{-14}$ C years BP (13C corrected).

 $(10.85 \pm 1.09)$  % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made on a small portion of the same evolved gas.

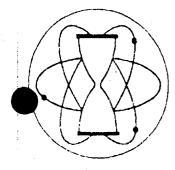
Comments:

 $\delta^{13}C_{PDB} =$ 

- 10.3 %

Notes: This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-27955

Date Received:

05/09/2001

Your Reference:

Skyline Mines

Date Reported:

05/22/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

Diagonal Submains E3 XC12 Fault 19 April 2001

AGE =

 $23.98 \pm 1.28$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

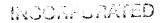
<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

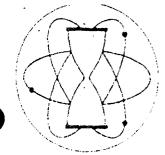
Comments:

 $\delta^{i3}C_{PDB} =$ 

-10.3 %c

Notes: This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-26389

Date Received:

01/06/2000

Your Reference:

Skyline Mine samples

Date Reported:

01/24/2000

Submitted by:

Mr. Keily Payne Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

16L E2 XC111/2 Mine 3L2 12/15/99

AGE =

14120 ± 610 14C years BP (13C corrected).

 $(17.25 \pm 1.32)\%$  of the modern  $(1950)^{-14}C$  activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

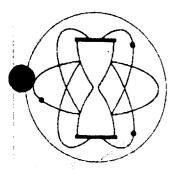
<sup>13</sup>C analysis was made on a small ponion of the same evolved gas.

Comments:

813CPDB =

-10.7 %.

Notes: This date is based upon the Libby hair life (5573 years) for 140. The error stated is ± 1d as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-2 1054

Date Received:

05/09/2001

Your Reference:

Skyline Mines

Date Reported:

05/22/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

9L E3 XC40 Borehole 19 April 2001

AGE =

 $23.53 \pm 1.64$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatmen:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

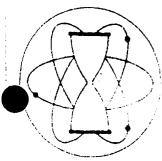
Comments:

 $\delta^{15}C_{PDB} =$ 

-11.2 %c

Notes

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- I s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-27952

Date Received:

05/09/2001

Your Reference:

Skyline Mines

Date Reported:

05/22/2001

Submitted av-

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E.

Lehi, Utah 84043

Sample Name:

16L XC12 18 April 2001

AGE =

 $16.02 \pm 1.99$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

Comments:

Extremely small sample yielding only 0.3 grams of carbon.

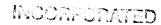
 $\delta^{13}C_{\text{PDB}} =$ 

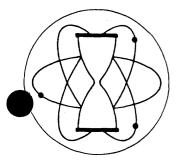
-9.9 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.







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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-29291

Date Received:

07/22/2002

Your Reference:

Skyline Mine

Date Reported:

07/31/2002

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

10 Left Sump 2 Jul 2002

AGE =

 $24.20 \pm 1.15$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

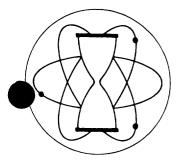
Comments:

 $\delta^{13}C_{PDB} =$ 

-10.4 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-29292

Date Received:

07/22/2002

Your Reference:

Skyline Mine

Date Reported:

07/31/2002

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

9 Left Horizontal Borehole 2 Jul 2002

AGE =

 $15.60 \pm 0.95$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed. under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

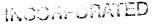
Comments:

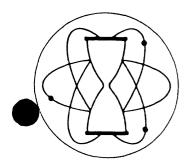
 $\delta^{13}C_{PDB} =$ 

-10.1 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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#### RADIOCARBON AGE DETERMINATION

#### REPORT OF ANALYTICAL WORK

Our Sample No. GX-21977

Date Received:

05/31/96

Your Reference: letter of 05/29/96

Date Reported:

06/12/96

Submitted by:

Ms. Kelly Payne

Mayo and Associates 710 East 100 North Lindon, Utah 84042

Sample Name: SKY \$7 (labeled SKY-M3-1L-TG-XC27) OKAY - KUP

grouhdwater precipitate

AGE =

7,065 + - 130 C-14 years BP (C-13 corrected).

(41.51 + - 0.68) % of the modern (1950) C-14 activity.

Description:

Sample of groundwater precipitate.

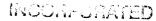
Pretreatment:

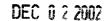
The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion of the same evolved gas.

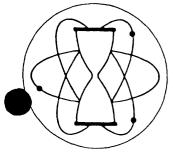
Comment:

$$\delta^{13}C_{PDB} = -10.9$$
 %

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm 1\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.







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#### RADIOCARBON AGE DETERMINATION

#### REPORT OF ANALYTICAL WORK

Our Sample No. GX - 21976

Date Received:

05/31/96

Your Reference: letter of 05/29/96

Date Reported:

06/12/96

Submitted by: Ms. Kelly Payne

Mayo and Associates 710 East 100 North Lindon, Utah 84042

(labeled SKY-M1-9L-E2-XC23 1/2) OKAY- KUP Sample Name: SKY 4

groundwater precipitate

AGE = 10,040  $\pm$ /- 380 C-14 years BP (C-13 corrected).

(28.65 + - 1.36) % of the modern (1950) C-14 activity.

Description: Sample of groundwater precipitate.

Pretreatment: The barium salt precipitate was rapidly vacuum filtered

and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion

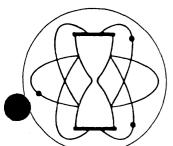
of the same evolved gas.

Comment:

$$\delta^{13}C_{PDB} = -10.3$$
 %

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm 1\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.





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#### RADIOCARBON AGE DETERMINATION

#### REPORT OF ANALYTICAL WORK

Our Sample No. GX-21975

Date Received:

05/31/96

Your Reference: letter of 05/29/96

Date Reported:

06/12/96

Submitted by:

Ms. Kelly Payne

Mayo and Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

SKY 3 (labeled SKY-M1-9L-E1-XC31 1/2) OKAY - KUP

groundwater precipitate

AGE =

12,400 +/- 330 C-14 years BP (C-13 corrected).

(21.36 + - 0.88) % of the modern (1950) C-14 activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

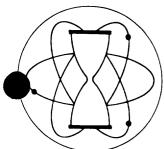
The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion

of the same evolved gas.

Comment:

$$\delta^{13}C_{PDB} = -8.7$$

Notes: This date is based upon the Libby half life (5570 years) for  ${}^{14}$ C. The error stated is  $\pm 1\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.



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## RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-28437

Date Received:

10/08/2001

Your Reference:

Skyline Mine

Date Reported:

10/19/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic

2695 N. 600 E. Lehi, Utah 84043

Sample Name:

Well JC-1 with coal 26 Sep 2001

AGE =

 $29.15 \pm 1.3$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

Comments:

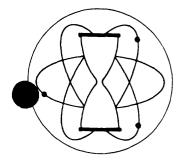
 $\delta^{13}C_{PDR} =$ 

-11.5 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-28439

Date Received:

10/08/2001

Your Reference:

Skyline Mine

Date Reported:

10/19/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

Electric Lake with coal 26 Sep 2001

AGE =

 $82.44 \pm 2.36$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

Comments:

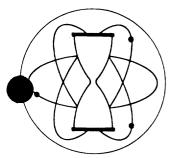
Extremely small sample yielding only 0.3 grams of carbon.

 $\delta^{13}C_{PDB} =$ 

-8.7 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-28438

Date Received:

10/08/2001

Your Reference:

Skyline Mine

Date Reported:

10/19/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic

2695 N. 600 E. Lehi, Utah 84043

Sample Name:

Electric Lake 26 Sep 2001

AGE =

 $72.44 \pm 2.26$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>15</sup>C analysis was made from a small portion of the same evolved gas.

Comments:

Extremely small sample yielding only 0.3 grams of carbon.

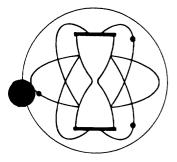
 $\delta^{13}C_{PDB} =$ 

-8.3 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-28436

Date Received:

10/08/2001

Your Reference:

Skyline Mine

Date Reported:

10/19/2001

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

Well JC-1 26 Sep 2001

AGE =

 $30.42 \pm 1.48$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed. under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>15</sup>C analysis was made from a small portion of the same evolved gas.

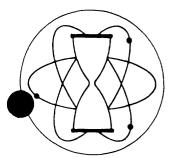
Comments:

 $\delta^{13}C_{PDB} =$ 

-11.8 %

Notes:

This date is based upon the Libby half life (5570 years) for 14C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-25119

Date Received:

12/28/98

Your Reference:

Skyline Mine

Date Reported:

03/09/99

Submitted by:

Mr. Travis L. Jensen Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

M1SSM E1 C102 12/17/98

AGE =

 $16,230 \pm 780 \, ^{14}\text{C}$  years BP (13C corrected).

 $(13.26 \pm 1.29)$  % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

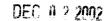
<sup>13</sup>C analysis was made on a small portion of the same evolved gas.

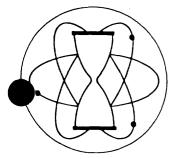
Comments:

 $\delta^{13}C_{PDB} =$ 

- 10.6 %

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-25316

Date Received:

01/15/99

Your Reference:

Skyline Mine

Date Reported:

03/24/99

Submitted by:

Mr. Travis L. Jensen Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

5LTG E1 C39 12/17/98

AGE =

13,320  $\pm$  630  $^{14}\text{C}$  years BP ( $^{13}\text{C}$  corrected). (19.05  $\pm$  1.49) % of the modern (1950)  $^{14}\text{C}$  activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

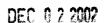
<sup>13</sup>C analysis was made on a small portion of the same evolved gas.

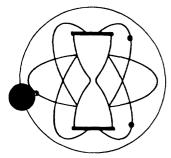
Comments:

 $\delta^{13}C_{PDB} =$ 

- 9.8 %

Notes: This date is based upon the Libby half life (5570 years) for 14C. The error stated is ± 1σ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-25565-PRI

Date Received:

04/14/99

Your Reference:

Willow Creek

Date Reported:

04/20/99

Submitted by:

Mr. Erik C. Petersen Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

14L HG E1 C37 Rib Water 12 APR 99

AGE =

21,460  $\pm$  1,420 <sup>14</sup>C years BP (<sup>13</sup>C corrected).

 $(6.91 \pm 1.21)$  % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

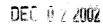
<sup>13</sup>C analysis was made on a small portion of the same evolved gas.

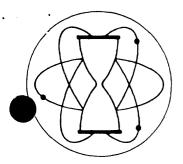
Comments:

 $\delta^{13}C_{PDB} =$ 

- 9.9 %

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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#### RADIOCARBON AGE DETERMINATION

#### REPORT OF ANALYTICAL WORK

Our Sample No.GX - 21667

Date Received:

02/15/96

Your Reference: letter of 02/06/96

Date Reported:

03/08/96

Submitted by: Ms. Kelly Payne

Mayo and Associates Consultants in

Hydrogeology

710 East 100 North Lindon, Utah 84042

Sample Name: \$34-12

groundwater

AGE =

1,970 +/- 160 C-14 years BP (C-13 corrected).

(78.26 + - 1.57) % of the modern (1950) C-14 activity.

Description:

Sample of BaCoz

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion

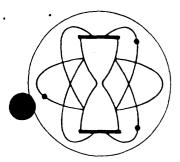
of the same evolved gas.

Comment:

$$\delta^{13}C_{PDB} = 13.0$$
 %

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm 1\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.





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#### RADIOCARBON AGE DETERMINATION

## REPORT OF ANALYTICAL WORK

Our Sample No. GX-21668

Date Received:

02/15/96

Your Reference: letter of 02/06/96

Date Reported:

03/08/96

Submitted by: Ms. Kelly Payne

Mayo and Associates Consultants in

Hydrogeology

710 East 100 North Lindon, Utah 84042

Sample Name: S15-3

groundwater

AGE =

3,790 +/- 175 C-14 years BP (C-13 corrected).

(62.40 + / - 1.34) % of the modern (1950) C-14 activity.

Description:

Sample of BaCoa

Pretreatment:

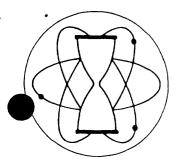
The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion of the same evolved gas.

Comment:

$$\delta^{13}C_{PDB} = -13.2$$
 %

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$  C. The error stated is  $\pm 1\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.





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#### RADIOCARBON AGE DETERMINATION

#### REPORT OF ANALYTICAL WORK

Our Sample No. GX-21669

Date Received:

02/15/96

Your Reference: letter of 02/06/96

Date Reported:

03/08/96

Submitted by:

Ms. Kelly Payne

Mayo and Associates Consultants in

Hydrogeology

710 East 100 North Lindon, Utah 84042

Sample Name: S22-11

groundwater

AGE =

2,260 +/- 180 C-14 years BP (C-13 corrected).

(75.49 + - 1.67) % of the modern (1950) C-14 activity.

Description:

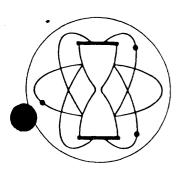
Sample of BaCoa

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion of the same evolved gas.

Comment:

$$\delta^{13}C_{POB} = -13.3$$
 %



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#### RADIOCARBON AGE DETERMINATION

#### REPORT OF ANALYTICAL WORK

Our Sample No. GX - 21670

Date Received:

02/15/96

Your Reference: letter of 02/06/96

Date Reported:

03/08/96

Submitted by: Ms. Kelly Payne

Mayo and Associates Consultants in

Hydrogeology

710 East 100 North Lindon, Utah 84042

Sample Name: \$13-2

groundwater

AGE =

1,780 + - 190 C - 14 years BP (C - 13 corrected).

(80.12 + - 1.91) % of the modern (1950) C-14 activity.

Description:

Sample of BaCoa

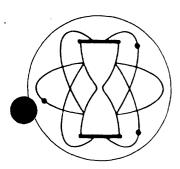
Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion

of the same evolved gas.

Comment:

$$\delta^{13}C_{PDB} = -12.0$$
 %



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DIV OF OIL GAS & MINING

RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No. GX - 21671

Date Received:

02/15/96

Your Reference: letter of 02/06/96

Date Reported:

03/08/96

Submitted by: Ms. Kelly Payne

Mayo and Associates Consultants in

Hydrogeology

710 East 100 North Lindon, Utah 84042

Sample Name: \$17-2

groundwater

AGE =

7,450 +/- 170 C-14 years BP (C-13 corrected).

(39.56 + - 0.83) % of the modern (1950) C-14 activity.

Description:

Sample of BaCoa

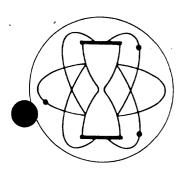
Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion

of the same evolved gas.

Comment:

 $\delta^{13}C_{POB} = -10.5$ 



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#### RADIOCARBON AGE DETERMINATION

#### REPORT OF ANALYTICAL WORK

Our Sample No. GX - 21672

Date Received:

02/15/96

Your Reference: letter of 02/06/96

Date Reported:

03/08/96

Submitted by: Ms. Kelly Payne

Mayo and Associates Consultants in

Hydrogeology

710 East 100 North Lindon, Utah 84042

Sample Name: \$36-12

groundwater

AGE =

1,290 +/- 100 C-14 years BP (C-13 corrected).

(85.16 + / - 1.05) % of the modern (1950) C-14 activity.

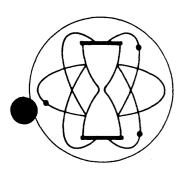
Description:

Sample of BaCoa

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion of the same evolved gas.

Comment:



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#### **RADIOCARBON AGE DETERMINATION**

#### REPORT OF ANALYTICAL WORK

Our Sample No. GX-22021

Date Received:

06/11/96

Your Reference: letter of 06/08/96

Date Reported:

07/23/96

Submitted by: M

Ms. Kelly Payne

Mayo and Associates 710 East 100 North Lindon, Utah 84042

Sample Name: Well #1

Well #1 W17-3

groundwater precipitate

AGE =

7,930 +/- 250 C-14 years BP (C-13 corrected).

(37.25 + - 1.15) % of the modern (1950) C-14 activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

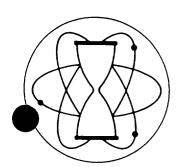
The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion

of the same evolved gas.

Comment:

Relatively small sample; approximately 0.9 grams carbon.

 $\delta^{13}C_{PDB} = ^{-10.8}$ 



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No. GX-22022

Date Received:

06/11/96

Your Reference: letter of 06/08/96

Date Reported:

07/23/96

Submitted by:

Ms. Kelly Payne

Mayo and Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

Well #2

W24-1

groundwater precipitate

AGE =

6,255 +/- 205 C-14 years BP (C-13 corrected).

(45.91 + / - 1.17) % of the modern (1950) C-14 activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

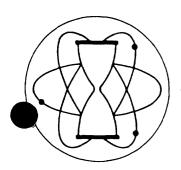
The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion

of the same evolved gas.

Comment:

Relatively small sample; approximately 0.82 grams carbon.

 $\delta^{13}C_{PDB} = -11.2$  %



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#### RADIOCARBON AGE DETERMINATION

#### REPORT OF ANALYTICAL WORK

Our Sample No. GX-22023

Date Received:

06/11/96

Your Reference: letter of 06/08/96

Date Reported:

07/23/96

Submitted by:

Ms. Kelly Payne

Mayo and Associates 710 East 100 North Lindon, Utah 84042

Sample Name: WQ-3-6

groundwater precipitate

AGE =

1,085 +/- 125 C-14 years BP (C-13 corrected).

(87.36 + / - 1.38) % of the modern (1950) C-14 activity.

Description:

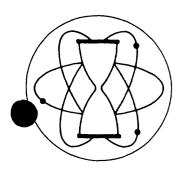
Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion of the same evolved gas.

Comment:

$$\delta^{13}C_{PDB} = -12.4$$
 %



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#### **RADIOCARBON AGE DETERMINATION**

REPORT OF ANALYTICAL WORK

Our Sample No. GX-22024

Date Received:

06/11/96

Your Reference: letter of 06/08/96

Date Reported:

07/23/96

Submitted by:

Ms. Kelly Payne

Mayo and Associates 710 East 100 North Lindon, Utah 84042

Sample Name: WQ-3-26

groundwater precipitate

AGE =

Modern, less than 100 C-14 years BP (C-13 corrected). (107.14 +/- 3.03) % of the modern (1950) C-14 activity.

Description:

Sample of groundwater precipitate.

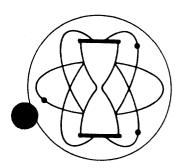
Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion

of the same evolved gas.

Comment:

Very small sample; approximately 0.32 grams carbon.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No. GX-22025

Date Received:

06/11/96

Your Reference: letter of 06/08/96

Date Reported:

07/23/96

Submitted by:

Ms. Kelly Payne

Mayo and Associates 710 East 100 North Lindon, Utah 84042

Sample Name: WQ-3-41

groundwater precipitate

AGE =

Modern, less than 100 C-14 years BP (C-13 corrected). (100.40 +/- 1.15) % of the modern (1950) C-14 activity.

Description:

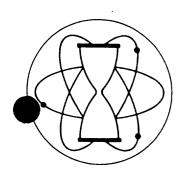
Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion of the same evolved gas.

Comment:

 $\delta^{13}C_{PDB} = -12.0$ 



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#### RADIOCARBON AGE DETERMINATION

#### REPORT OF ANALYTICAL WORK

Our Sample No. GX - 22026

Date Received:

06/11/96

Your Reference: letter of 06/08/96

Date Reported:

07/23/96

Submitted by:

Ms. Kelly Payne

Mayo and Associates 710 East 100 North Lindon, Utah 84042

Sample Name: WQ-4-12

groundwater precipitate

AGE =

1,520 +/- 200 100 C-14 years BP (C-13 corrected).

(82.78 + / - 2.02) % of the modern (1950) C-14 activity.

Description:

Sample of groundwater precipitate.

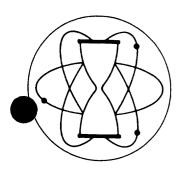
Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion

of the same evolved gas.

Comment:

$$\delta^{13}C_{PDB} = -13.7$$



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DIV OF OIL GAS & MINING

#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No. GX-22117

Date Received:

07/29/96

Your Reference: letter of 0.7/26/96

Date Reported:

08/14/96

Submitted by:

Mr. Kelly Payne Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name: Spring G-37

groundwater precipitate

AGE =

12,540 +/- 260 C-14 years BP (C-13 corrected).

(20.99 + - 0.69) % of the modern (1950) C-14 activity.

Description:

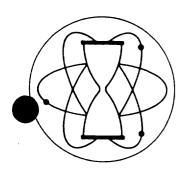
Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion of the same evolved gas.

Comment:

 $\delta^{13}C_{PDB} = -12.3$ 



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DEC # / 2002

DIV OF OIL GAS & MINING

#### RADIOCARBON AGE DETERMINATION

#### REPORT OF ANALYTICAL WORK

Our Sample No. GX-22118

Date Received:

07/29/96

Your Reference: letter of 07/26/96

Date Reported:

08/14/96

Submitted by:

Mr. Kelly Payne Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name: Green Canyon Spring

groundwater precipitate

AGE =

13,650 +/- 300 C-14 years BP (C-13 corrected).

(18.29 + - 0.69) % of the modern (1950) C-14 activity.

Description:

Sample of groundwater precipitate.

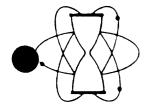
Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum to recover carbon dioxide from the barium carbonates for the analysis. C-13 analysis was made on a small portion of the same evolved gas.

Comment:

 $\delta^{13}C_{PDB} = -12.5$ 





### KRUEGER ENTERPRISES, INC.

DEC 0 2 2002

GEOCHRON LABORATORIES DIVISION

DIV OF OIL GAS & MINING

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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No. GX - 19554

Date Received:

10/12/93

Your Reference: letter of 10/04/93

Date Reported: 12/28/93

Submitted by: Mr. Erik Petersen Mayo and Associates Post Office Box 1960 Orem, Utah 84059

Sample Name: #3 WM1 C86 3-07 D

groundwater precipitate

15,725 + - 850 C - 14 years BP (C - 13 corrected). AGE =

(14.1 + /- 1.5) % of the modern (1950) C-14 activity.

Description: Sample of groundwater precipitate.

Pretreatment: The salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the carbonates for the analysis. C-13 analysis was made on a small portion of the same evolved gas.

Comment:

Small sample.

$$\delta^{13}C_{POB} = -10.8$$
 %

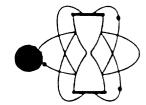
Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm 1\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



DEC 0 2 2002

as of January 1, 1993 INCORPORATED 711 Concord Avenue Cambridge, MA 02138 Telephone/Telefax Numbers remain the same

New Address



## KRUEGER ENTERPRISES, INC. DIV OF GIL CAS & MINING GEOCHRON LABORATORIES DIVISION

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#### RADIOCARBON AGE DETERMINATION

#### REPORT OF ANALYTICAL WORK

Our Sample No. GX - 19864

Date Received:

02/24/94

Your Reference: letter of 02/15/94

Date Reported: 03/21/94

Submitted by:

Erik C. Petersen

Mayo and Associates

P.O. Box 1960 Orem, Utah 84059

Sample Name: 1-01 S

groundwater precipitate

 $23,200 +5,500/-3,200 \times \times \times C-14 \text{ years BP (C-13 corrected)}$ . AGE =

(5.6 + / - 2.8) % of the modern (1950) C-14 activity.

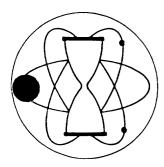
Description: Sample of precipitate from groundwater

Pretreatment: The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis. C-13analysis was made on a small portion of the same evolved gas.

Comment:

Very small sample; approximately 0.30 grams carbon.





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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-27347

Date Received:

10/27/2000

Your Reference:

Skyline & SUFCO Mines

Date Reported:

11/08/2000

Submitted by:

Dr. Alan Mayo

Mayo & Associates, Inc. 710 East 100 North Lindon, Utah 84042

Sample Name:

E6 XC 22 West Submains (lab 1325)

AGE =

 $21.15 \pm 1.21$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

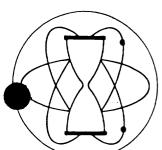
Comments:

 $\delta^{15}C_{PDB} =$ 

-10.3 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-27346

Date Received:

10/27/2000

Your Reference:

Skyline & SUFCO Mines

Date Reported:

11/08/2000

Submitted by:

Dr. Alan Mayo

Mayo & Associates, Inc. 710 East 100 North Lindon, Utah 84042

Sample Name:

14L H6 E1 C35 (lab 1328)

AGE =

 $12.98 \pm 2.04 \%$  of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

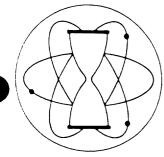
Comments:

 $\delta^{13}C_{PDB} =$ 

-10.2 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-26388

Date Received:

01/06/2000

Your Reference:

Skyline Mine samples

Date Reported:

01/24/2000

.70 9,63m

19 1

Submitted by:

Mr. Kelly Payne Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

14L E1 XC36 12/15/99

AGE =

13950 ± 640 14C years BP (13C corrected).

 $(17.66 \pm 1.41)\%$  of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made on a small portion of the same evolved gas.

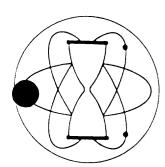
Comments:

-10.1 %

 $\delta^{13}C_{PDB} =$ 

\_\_\_\_\_

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-26389

Date Received:

01/06/2000

Your Reference:

Skyline Mine samples

Date Reported:

01/24/2000

1000

Submitted by:

Mr. Kelly Payne Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

16L E2 XC11<sup>1/2</sup> Mine 3L2 12/15/99

AGE =

14120  $\pm$  610 <sup>14</sup>C years BP (<sup>13</sup>C corrected).

 $(17.25 \pm 1.32)\%$  of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed. under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

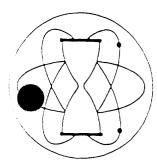
<sup>13</sup>C analysis was made on a small portion of the same evolved gas.

Comments:

 $\delta^{13}C_{PDB} =$ 

-10.7 %.

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Dur Sample No.

GX-25316

Date Received:

01/15/99

Your Reference:

Skyline Mine

Date Reported:

03/24/99

Submitted by:

Mr. Travis L. Jensen Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

5LTG E1 C39 12/17/98

AGE =

 $13,320 \pm 630$  <sup>14</sup>C years BP (<sup>13</sup>C corrected).

 $(19.05 \pm 1.49)$  % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

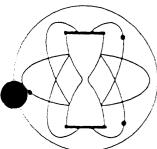
<sup>13</sup>C analysis was made on a small portion of the same evolved gas.

Domments:

13CPDE =

- 9.8 %.

Notes: This date is based upon the Libby half life (5570 years) for 14C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-25492-PRI

Date Received:

03/24/99

Your Reference:

Skyline Mine

Date Reported:

03/30/99

Submitted by:

Mr. Erik C. Petersen Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

14L HG E1 C35 Roof 22 Mar 99

AGE =

 $17,840 \pm 810 \, ^{14}\text{C}$  years BP (13C corrected).

 $(10.85 \pm 1.09)$  % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed. under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

13C analysis was made on a small portion of the same evolved gas.

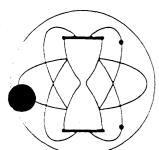
Comments:

 $\delta^{13}C_{PDB} =$ 

- 10.3 %.

Notes: This date is based upon the Libby half life (5570 years) for 14C. The error stated is ± 1σ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-25491-PRI

Date Received:

03/24/99

Your Reference:

Skyline Mine

Date Reported:

03/30/99

Submitted by:

Mr. Erik C. Petersen Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

14L HG E1 C35 Floor 22 Mar 99

AGE =

 $18,800 \pm 1,090 \, ^{14}\text{C}$  years BP (13C corrected).

 $(9.63 \pm 1.30)$  % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

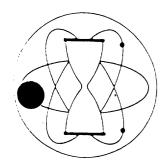
<sup>13</sup>C analysis was made on a small portion of the same evolved gas.

Comments:

δ<sup>13</sup>C<sub>PDE</sub> =

- 9.7 %.

Notes: This date is based upon the Libby half life (5570 years) for  $^{14}$ C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-25565-PRI

Date Received:

04/14/99

Your Reference:

Willow Creek

Date Reported:

04/20/99

Submitted by:

Mr. Erik C. Petersen Mayo & Associates 710 East 100 North Lindon, Utah 84042

Sample Name:

14L HG E1 C37 Rib Water 12 APR 99

AGE =

21,460  $\pm$  1,420 <sup>14</sup>C years BP (<sup>13</sup>C corrected).

 $(6.91 \pm 1.21)$  % of the modern (1950) <sup>14</sup>C activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

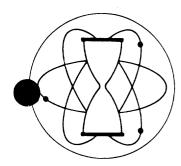
<sup>13</sup>C analysis was made on a small portion of the same evolved gas.

Comments:

δ<sup>13</sup>C<sub>PDE</sub> =

- 9.9 %.

Notes: This date is based upon the Libby half life (5570 years) for 14C. The error stated is  $\pm$  1 $\sigma$  as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-29081

Date Received:

04/29/2002

Your Reference:

Skyline Mine

Date Reported:

05/21/2002

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

East Submains E1 XC5 Fault

4/10/2002

AGE =

 $15.17 \pm 0.95$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

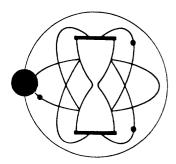
Comments:

 $\delta^{13}C_{PDB} =$ 

-10.7 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-29078

Date Received:

04/29/2002

Your Reference:

Skyline Mine

Date Reported:

05/21/2002

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E.

Lehi, Utah 84043

Sample Name:

9 Left Borehole XC59 10 April 2002

AGE =

 $16.91 \pm 1.06 \%$  of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>15</sup>C analysis was made from a small portion of the same evolved gas.

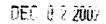
Comments:

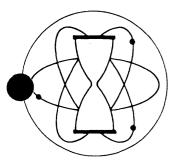
 $\delta^{13}C_{PDR} =$ 

-10.4 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-29079

Date Received:

04/29/2002

Your Reference:

Skyline Mine

Date Reported:

05/21/2002

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

Diagonal Fault 10 April 2002

AGE =

 $11.91 \pm 1.95$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>15</sup>C analysis was made from a small portion of the same evolved gas.

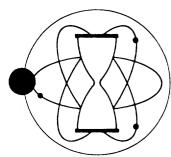
Comments:

 $\delta^{13}C_{PDB} =$ 

-10.3 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



DEC 0 2 2002

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#### RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-29080

Date Received:

04/29/2002

Your Reference:

Skyline Mine

Date Reported:

05/21/2002

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E.

Lehi, Utah 84043

Sample Name:

11 Left Headgate E1 XC62 10 April 2002

AGE =

 $25.57 \pm 0.84$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

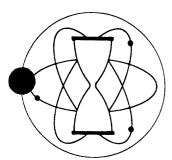
Comments:

 $\delta^{13}C_{PDB} =$ 

-10.5 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-29083

Date Received:

04/29/2002

Your Reference:

Skyline Mine

Date Reported:

05/21/2002

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

11 Left Headgate E1 XC39 Fault 10 April 2002

 $\Delta$ GE =

 $2.29 \pm 1.09$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>15</sup>C analysis was made from a small portion of the same evolved gas.

Comments:

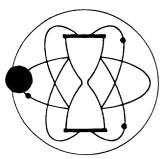
 $\delta^{15}C_{PDB} =$ 

-10.9 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

DEC 0 3 5003



## **GEOCHRON LABORATORIES**

DIV OF OIL GAS & MINING

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711 Concord Avenue → Cambridge, Massachusetts 02138-1002 → USA t (617) 876-3691 f (617) 661-0148 www.geochronlabs.com

RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-29082

Date Received:

04/29/2002

Your Reference:

Skyline Mine

Date Reported:

05/21/2002

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E.

Lehi, Utah 84043

Sample Name:

East Submains E3 XC14 Fault 10 April 2002

 $\triangle GE =$ 

 $17.36 \pm 0.77$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

Comments:

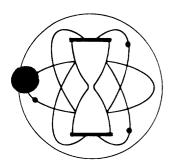
 $\delta^{15}C_{PDB} =$ 

-10.3 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.





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DEC 11 5 Sund

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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-29084

Date Received:

04/29/2002

Your Reference:

Skyline Mine

Date Reported:

05/21/2002

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

11 Left 25 April 2002

 $\bullet$ GE =

 $7.26 \pm 1.86$  % of the modern (1950) <sup>14</sup>C years activity.

Description:

Sample of groundwater precipitate.

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

Comments:

 $\delta^{13}C_{PDB} =$ 

-10.1 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

# Brigham Young University Stable Isotope Laboratory Analytical Report

Laboratory Numbers: 2587, 2609-2612, 2614

Customer: Skyline/Erik Petersen

Material Analyzed: water

Date Analyzed: October, 2001

 $\frac{6}{6} \delta^{18} O_{VSMOW}$  and  $\delta D_{VSMOW}$  pair @ \$25/sample = \$150

Total = \$150

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DEC		?	2002
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Sample	$\delta^{18}O_{VSMOW}$	± 1 s.d.	$\delta D_{VSMOW}$	± 1 s.d.
Tower #1 Well (2587)	-15.13	0.1	-112.86	1
Well JC-1 (2609)	-17.50	0.1	-128.41	1
Upper Electric Lake (2610)	-16.07	0.1	-119.19	1
JC-1 w/coal (2611)	-17.50	0.1	-128.93	1
Upper Electric Lake w/coal (2612)	-15.92	0.1	-120.36	1
Electric Lake at Outlet (2614)	-14.43	0.1	-110.00	1

#### **NOTES:**

$$\delta^{18}O_{VSMOW (sample)} = [(^{18}O/^{16}O)_{sample} - (^{18}O/^{16}O)_{VSMOW} / (^{18}O/^{16}O)_{VSMOW}] * 1000$$

$$\delta D_{VSMOW(sample)} = [(^2H/^1H)_{sample} - (^{12}H/^1H)_{VSMOW} / (^2H/^1H)_{VSMOW}] * 1000$$

$$\delta^{13}C_{\text{VPDB (sample)}} = \left[ (^{13}C/^{12}C)_{\text{sample}} - (^{13}C/^{12}C)_{\text{VPDB}} / (^{13}C/^{12}C)_{\text{VPDB}} \right] * 1000$$

 $\delta^{18}$ O<sub>VSMOW (sample)</sub>,  $\delta$ D<sub>VSMOW (sample)</sub> and  $\delta^{13}$ C<sub>VPDB (sample)</sub> are the measured "delta" values for the given sample. ( $^{18}$ O/ $^{16}$ O)<sub>sample</sub>, ( $^{2}$ H/ $^{1}$ H)<sub>sample</sub> and ( $^{13}$ C/ $^{12}$ C)<sub>sample</sub> are raw isotope ratios, and ( $^{18}$ O/ $^{16}$ O)<sub>VSMOW</sub> ( $^{2}$ H/ $^{1}$ H)<sub>VSMOW</sub> are the defined isotope ratios for hydrogen and oxygen of the VSMOW international standard. VPDB values for carbon are produced by analysis with reference gases calibrated to NBS-19.

<sup>&</sup>lt;sup>1</sup>Values are normalized to the VSMOW/SLAP scale (Coplen, 1988)

<sup>&</sup>lt;sup>2</sup>Values were determined by analysis with reference gases calibrated to NBS-19

skyline

<u>Sample</u>	Delta O18	Delta D	
<u>Name</u>	wrt VSMOW	wrt VSMOW	
14L E1 XC36 12/15/99	-18.05	-122.49	
14L E1 XC36 12/15/99	-18.03	-122.87	
16L E2 XC11.5 12/15/99	-18.08	-124.89	
16L E2 XC11.5 12/15/99	-18.09	-125.52	

INCORPORATED

DEC 0 2 2002

DIVIOR OIL GAS & MITTING

#### Summry21.xls

<u>Sample</u>	Delta O18	Delta D
Name	wrt VSMOW	wrt VSMOW
14L HG E1 C35 Floor 22 Mar 99	-17.81	-130.32
14L HG E1 C35 Floor 22 Mar 99	-17.87	-130.88
14L HG E1 C35 Roof 22 Mar 99	-17.87	-133.86
14L HG E1 C35 Roof 22 Mar 99	-17.91	-133.77
14L HG E1 C23 R.D. 22 Mar 99	-17.45	-131.12
14L HG E1 C23 R.D. 22 Mar 99	-17.45	-130.95
WM E2 C73 R.D. 22 Mar 99	-17.98	-137.59
WM E2 C73 R.D. 22 Mar 99	-18.02	-136.70

## MICORPORATED

DEC 0 2 2002

DIV OF GIL GAD & MINING

Sample	Delta O18	<u>Delta D</u>
Name	wrt VSMOW	wrt VSMOW
14LHGE1C37 Rib Water 4/12/99	-17.74	-132.33
14LHGE1C37 Rib Water 4/12/99	-17.75	-132.28

MOCAFURATED

DEC 0 2 2002

DIV OF OIL GAS & MINING

Sample	Delta O18	<u>Delta D</u>
<u>Name</u>	wrt VSMOW	wrt VSMOW
19-175	-17.54	-131.10
19-175	-17.55	-131.33
2-413	-17.28	
2-413	-17.31	-128.79
21-222	-16.83	
21-222	-16.91	-126.24
28-110	-16.85	
28-110	-16.92	
29-133	-17.02	<del> </del>
29-133	-17.07	
29-138	-16.90	
29-138	-16.85	
3-290	-17.27	
3-290	-17.25	
31-181	-16.94	
31-181	-16.99	
32-183	-16.85	<del></del>
32-183	-16.88	
32-276	-16.92	
32-276	-16.99	
32-277	-16.77	
32-277	-16.84	
32-279	-17.13	
32-279	-17.23	
33-268	-17.31	
33-268	-17.28	
33-271	-17.13	<del></del>
33-271	-17.18	
33-273	-17.49	1
33-273	-17.47	
4-173	-17.47	-130.92
4-173	-17.53	
4-429	-17.03	
4-429	-16.99	
5-231	-17.02	
5-231	-17.0	
5-238	-16.7°	
5-238	-16.79	
7-242	-16.28	-120.81
7-242	-16.20	
8-253	-17.2	
8-253	-17.3	
C-1	-16.3	
C-1	-16.2	
C-2	-16.13	-123.88
C-2	-16.0	6 -123.80
C-3	-16.8	
C-3	-16.7	
C-4	-16.2	

### MOONFURGER

DEC 0 2 2002

DIV OF OIL GAS & MINING

#### SUMMARY1.XLS

C-4	-16.17	-124.05
C-5	-16.57	-124.05
C-5	-16.47	-124.13
MSS-1	-17.07	-128.83
MSS-1	-17.08	-128.70
MST-1	-16.76	-125.80
MST-1	-16.71	-125.87
MST-2	-17.13	-128.39
MST-2	-17.18	-128.82
MST-3	-16.97	-127.26
MST-3	-17.03	-127.60

### INCORPORATED

DEC 0 2 2002

DIV OF OIL GAS & MINING

Sample	Delta O18	Delta D
Name	wrt VSMOW	wrt VSMOW
C-1	-16.36	-125.74
C-1	-16.31	-124.94
C-2	-15.75	-119.33
C-2	-15.76	-119.38
C-3	-16.46	-124.73
C-3	-16.52	-124.99
C-4	-16.29	
C-4	-16.19	
C-5	-16.07	
C-5	-16.12	
MST-1	-16.24	
MST-1	-16.34	
MST-2	-16.42	
MST-2	-16.36	
MST-3	-16.29	
MST-3	-16.25	
33-271	-16.44	
33-271	-16.53	
29-138	-16.32	<del></del>
29-138	-16.25	
32-183	-16.39	<del></del>
32-183	-16.46	
5-231	-16.63	<del></del>
5-231	-16.71	
4-173	-17.04	
4-173	-16.99	
33-273	-17.11	
33-273	-17.16	
28-110	-17.18	
28-110	-17.13	-128 78
21-222	-16.81	
21-222	-16.82	-128.24
29-133	-16.61	
29-133	-16.53	-124.32
8-253	-17.33	
8-253	-17.32	
32-279	-16.76	
32-279	-16.86	-125.03
7-242?	-16.36	-122.91
7-242?	-16.46	
32-277	-16.60	
32-277	-16.61	
2-413	-16.88	
2-413	-16.98	
3-290	-16.84	<del></del>
3-290	-16.82	<del></del>
19-175	-17.02	
19-175	-17.1	

## INCOMPORATED

DEC 0 7 2002

DIVIOR OIL GAD SIMPLING

FLAT CANYON FROM MASS

Sample	Delta O18	Delta D
Name	wrt VSMOW	wrt VSMOW
C-1	-16.36	-125.74
C-1	-16.31	
C-2	-15.75	
C-2	-15.76	
C-3	-16.46	
C-3	-16.52	
C-4	-16.29	
C-4	-16.19	
C-5	-16.07	
C-5	-16.12	
MST-1	-16.24	
MST-1	-16.34	
MST-2		
MST-2	-16.42	
MST-3	-16.36 -16.29	
MST-3		<del></del>
33-271	-16.25	
	-16.44	
33-271	-16.53	
29-138	-16.32	
29-138	-16.25	
32-183	-16.39	
32-183	-16.46	
5-231	-16.63	
5-231	-16.71	
4-173	-17.04	
4-173	-16.99	
33-273	-17.11	
33-273	-17.16	
28-110	-17.18	
28-110	-17.13	
21-222	-16.81	
21-222	-16.82	
29-133	-16.61	
29-133	-16.53	
8-253	-17.33	-133.65
8-253	-17.32	
32-279	-16.76	
32-279	-16.86	
7-242?	-16.36	
7-242?	-16.46	
32-277	-16.60	
32-277	-16.6	
2-413	-16.8	
2-413	-16.98	
3-290	-16.8	
3-290	-16.8	
19-175	-17.0	
19-175	-17.1	1 -130.21

DEC 0 2 2002

DIV OF OIL GAS & MILLING

FLAT CANYON
FROM MASS

<u>Sample</u>	Delta O18	<u>Delta D</u>
<u>Name</u>	wrt VSMOW	wrt VSMOW
19-175	-17.54	-131.10
19-175	-17.55	-131.33
2-413	-17.28	-129.20
2-413	-17.31	-128.79
21-222	-16.83	-126.02
21-222	-16.91	-126.24
28-110	-16.85	-127.37
28-110	-16.92	-127.17
29-133	-17.02	-127.75
29-133	-17.07	-128.04
29-138	-16.90	-127.60
29-138	-16.85	-127.06
3-290	-17.27	-129.74
3-290	-17.25	-130.31
31-181	-16.94	
31-181	-16.99	-126.66
32-183	-16.85	
32-183	-16.88	
32-276	-16.92	
32-276	-16.99	
32-277	-16.77	
32-277	-16.84	-124.03
32-279	-17.13	
32-279	-17.23	
33-268	-17.31	<del></del>
33-268	-17.28	
33-271	-17.13	
33-271	-17.18	
33-273	-17.49	
33-273	-17.47	
4-173	-17.47	-130.92
4-173	-17.53	
4-429	-17.03	
4-429	-16.99	
5-231 5-231	-17.02	
5-231	-17.01	<del></del>
5-238	-16.71	
7-242	-16.75	<del></del>
7-242	-16.28 -16.26	
8-253	-17.25	
8-253	-17.23	
C-1	-16.34	
C-1	-16.28	
C-2	-16.13	
C-2	-16.06	
C-2	-16.80	
C-3	-16.73	
C-4	-16.26	<del></del>
10-7	-10.20	-124.00

## MOURFURATED

DEC 0 2 2011

### INCORPORATED

DEC # 2 2002

Sample	Delta O18	Delta D
<u>Name</u>	wrt VSMOW	wrt VSMOW
19-175	-17.54	-131.10
19-175	-17.55	-131.33
2-413	-17.28	-129.20
2-413	-17.31	-128.79
21-222	-16.83	-126.02
21-222	-16.91	-126.24
28-110	-16.85	<del> </del>
28-110	-16.92	
29-133	-17.02	
29-133	-17.07	-128.04
29-138	-16.90	<del>}</del>
29-138	-16.85	
3-290	-17.27	
3-290	-17.25	
31-181	-16.94	i
31-181	-16.99	
32-183	-16.85	
32-183	-16.88	
32-276	-16.92	<del></del>
32-276	-16.99	ļ
32-277	-16.77	
32-277	-16.84	<del></del>
32-279	-17.13	<del></del>
32-279	-17.13	
33-268	-17.31	<del></del>
33-268	-17.28	<u> </u>
33-271	-17.13	
33-271	-17.18	
33-273	-17.49	
33-273	-17.47	
4-173	-17.47	
4-173	-17.53	
4-429	-17.03	4
4-429	-16.99	<del></del>
5-231	-17.02	
5-231	-17.01	
5-238	-16.71	
5-238	-16.75	
7-242	-16.28	<del></del>
7-242	-16.26	<del></del>
8-253	-17.25	
8-253	-17.23	
C-1	-17.31	
C-1	-16.28	
C-2	-16.13	
C-2	-16.06	<del></del>
C-2	-16.80	
C-3	-16.73	
C-4	-16.26	<del> </del>
10-7	-10.20	J: -124.0U

### SUMMARY1.XLS

C-4	-16.17	-124.05
C-5	-16.57	-124.05
C-5	-16.47	-124.13
MSS-1	-17.07	-128.83
MSS-1	-17.08	-128.70
MST-1	-16.76	-125.80
MST-1	-16.71	-125.87
MST-2	-17.13	-128.39
MST-2	-17.18	-128.82
MST-3	-16.97	-127.26
MST-3	-17.03	-127.60

## MOORFORATED

DEC 0 2 2002

Sample	Delta O18	Delta D
Name	wrt VSMOW	wrt VSMOW
14LHGE1C37 Rib Water 4/12/99	-17.74	-132.33
14I HGF1C37 Rib Water 4/12/99	-17.75	-132.28

INCOMPURATED

DEC 0 2 2002

|--|--|

DEC	0	2	2002
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Sample	Delta O18	Delta D
<u>Name</u>	wrt VSMOW	wrt VSMOW
14L HG E1 C35 Floor 22 Mar 99	-17.81	-130.32
14L HG E1 C35 Floor 22 Mar 99	-17.87	-130.88
14L HG E1 C35 Roof 22 Mar 99	-17.87	-133.86
14L HG E1 C35 Roof 22 Mar 99	-17.91	-133.77
14L HG E1 C23 R.D. 22 Mar 99	-17.45	-131.12
14L HG E1 C23 R.D. 22 Mar 99	-17.45	-130.95
WM E2 C73 R.D. 22 Mar 99	-17.98	-137.59
WM E2 C73 R.D. 22 Mar 99	-18.02	-136.70

#### Summry34.xts

Sample	Delta O18	Delta D		
Name	wrt VSMOW	wrt VSMOW		
14L E1 XC36 12/15/99	-18.05	-122.49		
14L E1 XC36 12/15/99	-18.03	-122.87		
16L E2 XC11.5 12/15/99	-18.08	-124.89		
16L E2 XC11.5 12/15/99	-18.09	-125.52		

Skyline

MCCORPUTATION

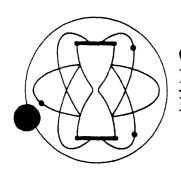
DEC 0 2 2002

#### SUMMARY1.XLS

C-4	-16.17	-124.05
C-5	-16.57	-124.05
C-5	-16.47	-124.13
MSS-1	-17.07	-128.83
MSS-1	-17.08	-128.70
MST-1	-16.76	-125.80
MST-1	-16.71	-125.87
MST-2	-17.13	-128.39
MST-2	-17.18	-128.82
MST-3	-16.97	-127.26
MST-3	-17.03	-127.60

INCOM GRATED

DEC 0 2 2002



# GEOCHRON LABORATORIES a division of KRUEGER ENTERPRISES, INC.

711 CONCORD AVENUE + CAMBRIDGE, MASSACHUSETTS 02138 + U . S . A TELEPHONE: (617) 876-3691 TELEFAX: (617) 661-0148

MCCH-ORATED

DEC 0 2 2002

DIV OF OIL GAS & MINING

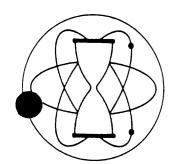
Erik C. Petersen Mayo and Associates P.O. Box 1960 Orem, UT 84059 Date Received: 10/12/93

Date Reported: 11/16/93

Reference: Skyline samples

### REPORT OF TRITIUM ANALYSES

Our Lab. No.	Your Sample No.	<u>Tritium Units</u>
T-04794	#1 WM6 C94 1-03 D	5.6 +/- 2.7
T-04795	#3 WM1 C86 3-07 D	6.7 +/- 2.7



## GEOCHRON LABORATORIES a division of KRUEGER ENTERPRISES, INC.

DEC 0 2 2002

DIV OF OIL GAS & MINING

711 CONCORD AVENUE → CAMBRIDGE, MASSACHUSETTS 02138 → U.S.A TELEPHONE: (617) 876-3691 TELEFAX: (617) 661-0148

Erik C. Petersen Mayo and Associates P.O. Box 1960 Orem, UT 84059

Date Received: 02/02/94

Date Reported: 03/09/94

Reference: Skyline sample

#### REPORT OF TRITIUM ANALYSES

Our Lab. No. Your Sample No. Tritium Units T-4840 1-01S - 2.7 +/- 2.6

INBOX: 2 of 2

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Date Tue, 25 Jan 2000 15:18:38 -0500

From Charlene Grall < cgrall@rsmas.miami.edu>

To petersen@enol.com

Subject Skyline Coal results

Parts Message Source

INCOMPONATED

DEC II 2 2002

DIV OF OIL GAS & MINING

Here they are:

Client: MAYO and ASSOCIATES - SKYLINE COAL

Purchase Order:

99-0017

Recvd: 00/01/03

801/796-0211

Contact: K. Payne

785-2387

Job# : 1282

710 E. 100 North, (F)

Lindon, UT

Final: PRELIMINARY RESULTS

84042

JOB.SX REFDATE QUANT ELYS

Cust LABEL INFO

SKYLINE - 14L E1 XC36

1282.01 991215 1000 275 0.02

1282.02 991215 1000 275

SKYLINE - 16L E2 XC11 1/2

::::^:^:^:^:^:^:^:^:^:^:^:^::::

Charlene Grall :: Tritium Laboratory

University of Miami/RSMAS

4600 Rickenbacker Cswy. :: Miami, Florida 33149 USA

(305)361-4119 :: (305)361-4112fax

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Client: MAYO and ASSOCIATES - SKYLINE MINE Recvd: 99/03/24

Purchase Order: 99-0006

Contact: K. Payne 801/796-0211

710 E. 100 North, (F) 785-2387

Final: 99/05/18

Job# : 1194

Lindon, UT 84042

	LABEL	INFO		REFDATE			TU	eTU
MAYO	- 14L	HG E1 C35 FLOOR	1194.01	990322 990322	1000	250	0.11	

DEC 0 2 2002

Client: MAYO and ASSOCIATES - WILLOW CREEK

Recvd: 99/04/14, 03/29

Job# : 1205

Final: 99/05/18

Purchase Order: 99-0009

Contact: K. Payne 801/796-0211

710 E. 100 North, (F) 785-2387

Lindon, UT 84042

JOB.SX REFDATE QUANT ELYS TU Cust LABEL INFO \_\_\_\_\_\_ MAYO - 14LHGE1C37 RIB WATER 1205.01 990412 1000 256 0.02 0.09

MOORFURATED

DEC 0.7 2002

Client: MAYO and ASSOCIATES - SKYLINE COAL

Purchase Order: 99-0017 Recvd : 00/01/03 Contact: K. Payne 801/796-0211

Job# : 1282 710 E. 100 North, (F) 785-2387

Final : 00/02/07 Lindon, UT 84042

Cust LABEL INFO	JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
SKYLINE - 14L E1 XC36 SKYLINE - 16L E2 XC11 1/2		991215 991215			0.02 0.12	0.09

NCCAPORATED

DEC 0 2 2002

Client: MAYO and ASSOCIATES - SKYLINE COAL

Purchase Order:2000-

Recvd : 00/10/02 Contact: K. Payne 801/796-0211 710 E. 100 North, (F) 785-2387

Job# : 1397 Final : 00/11/01

Lindon, UT 84042

	ABEL INFO		REFDATE	-		TU	eTU
MAYO- 14	4L HGE1 XC35	1397.01	000922 000922	1000	250 216	-0.02 0.00	

MOURFURATED

DEC 0 2 2000

#### GENERAL COMMENTS ON TRITIUM RESULTS

DEC 0 2 2002

#### Tritium Scale

DW OF OIL GAS & MINING

Tritium concentrations are expressed in TU, where 1 TU indicates a Tritium/Hydrogen ratio of  $10^{-18}$ . The values refer to the tritium scale of U.S. National Institute of Science and Technology (formerly NBS), and based on their tritium water standard #4926. Age corrections and conversions are made using the half-life of 12.43 years, i.e.,  $\lambda$  = 5.576% year<sup>-1</sup>. In this scale, 1 TU is 7.088 dpm/kg H<sub>2</sub>O, or 3.193 pCi/kg H<sub>2</sub>O, or 0.1181 Bq/kg H<sub>2</sub>O (Bq = disint/sec).

TU values are calculated for the date of sample collection, REFDATE in the table, as provided by the submitter. If no such date is available, the date of the sample's arrival at our laboratory is used.

The stated errors, eTU, are one standard deviation (1 sigma), including all conceivable contributions. In the table, QUANT is the quantity of sample received, and ELYS is the amount of water taken for electrolytic enrichment. DIR means direct run (no enrichment).

Remark: A revised value for the half-life, 12.32 years, has recently been recommended by the International Atomic Energy Agency. The use of this number (instead of 12.43 years) would ,in practice, only affect the conversion of dpm to TU, and the correction would amount to 0.9 % in reported TU-values. This is insignificant since our reported values carry 1 sigma uncertainties of 3 % or more. We are, therefore, NOT changing our reporting standard for the time being. (It is interesting to note that before 1982 the recommended value was 12.26 years)

#### Very low tritium values

In some cases, negative TU values are listed. Such numbers can occur because the net tritium count rate is, in principle, the difference between the count rate of the sample and that of a tritium-free sample (background count or blank sample). Given a set of "unknown" samples with no tritium, the distribution of net results should become symmetrical around 0 TU. The negative values are reported as such for the benefit of allowing the user unbiased statistical treatment of sets of the data. For other applications, 0 TU should be used.

#### Additional information

Refer to Services Rendered (Tritium), Section II.8, in the "Tritium Laboratory Price Schedule; Procedures and Standards; Advice on Sampling", at our Web-site www.miami.rsmas.edu/groups/tritium.

Tritium efficiencies and background values are somewhat different in each of the nine counters and values are corrected for cosmic ray intensity, gas pressure and other parameters. For tritium, the efficiency is typically 1.00 cpm per 100 TU (direct counting). At 50x enrichment, the efficiency is equivalent to 1.00 cpm per 2.4 TU. The background is typically 0.3 cpm, known to about ± 0.02 cpm. Our reported results include not only the Poisson statistics, but also other experimental uncertainties such as enrichment error, etc.

End

Client: MAYO and ASSOCIATES - SKYLINE MINE Purchase Order: ON FILE

Recvd: 99/01/04 Contact: K. Payne 801/796-0211 Job#: 1164 710 E. 100 North, (F) 785-2387

Final: 99/02/18 Lindon, UT 84042

Cust	LABEL INFO	 JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
MAYO-	M1SS E1 5LTG E1		981217 981217		275 275	0.06 -0.06	

INCORPURATED

DEC 0 / Mile

Client: MAYO and ASSOCIATES - SKYLINE MINE Purchase Order: 97-113

Recvd : 97/10/30 Contact: K. Payne 801/796-0211 710 E. 100 North, (F) 785-2387 Job# : 1009

Final : 97/11/18 Lindon, UT 84042

Cust LABEL INFO	JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
MAYO-SKY-MST-3	1009.01	970911	1000	275	13.1	0.4
MAYO-SKY-8-253	1009.02	971008	1000	275	29.7	1.0
MAYO-SKY-2-413	1009.03	971008	1000	275	14.9	0.5
MAYO-SKY-29-138	1009.04	971008	1000	275	12.9	0.4
MAYO-SKY-7-242	1009.05	971009	1000	269	10.5	0.3
MAYO-SKY-32-279	1009.06	971009	1000	275	14.0	0.5

INCORPUTATED

DEC 0 2 2002

DIV OF OIL GAS & MARNO

Client: MAYO and ASSOCIATES - FLAT CANYON Purchase Order: 98-0012

Recvd: 98/08/06 Contact: K. Payne 801/796-0211

Job# : 1106 710 E. 100 North, (F) 785-2387

Final: 98/10/07 Lindon, UT 84042

Cust LABEL INFO	JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
MAYO- MST-3 PRE-TEST	1106.01	980721	1000	192	7	5
MAYO- MST-3	1106.01	980721	1000	192	10.3 *	0.3
MAYO- 2-413	1106.02	980722	1000	DIR	15	3
MAYO- 8-253	1106.03	980721	1000	DIR	30	3
MAYO- 32-279	1106.04	980721	1000	DIR	15	3
MAYO- 29-138	1106.05	980721	1000	DIR	14 *	3

<sup>\*</sup> Average of duplicate runs

MOUNTURATED

DEC 0 2 2002

Client: MAYO and ASSOCIATES - SKYLINE COAL Purchase Order: 99-0017

Recvd: 00/01/03 Contact: K. Payne 801/796-0211

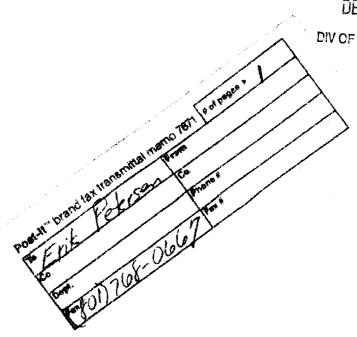
Job# : 1282 710 E. 100 North, (F) 785-2387

Final: 00/02/07 Lindon, UT 84042

SKYLINE - 14L E1 XC36 1282.01 991215 1000 275 0.02 0.09	Cust LABEL INFO		REFDATE	_		TU	eTU
AMERICAN ASSESSED 1/4 ASSESSED 2000 2000 2000 2000 2000 2000 2000 20							
SKYLINE - 16L E2 XC11 1/2 1282.02 991215 1000 275 0.12 0.09	SKYLINE - 16L E2 XC11 1/2	1282.02	991215	1000	275	0.12	0.09

INCORPURATED

DEC 0 2 2002



Client: MAYO AND ASSOCIATES

Recvd: 96/07/29 Job#: 869 Final: 96/08/26

Purchase Order: 41-7261-6
Contact: K. Payne, 801/785-2385,-2387(f)
710 E. 100 N., Lindon, UT 84042
FOR: Skyline Coal Co., 801/637-7925

Cust LABEL INFO		JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
MAYO- ALPINE WELL	SPRING	869.01	960723	1000	275	-0.02	0.09
MAYO- SPRING G-37		869.02	960723	1000	274	0.05	0.09
MAYO- GREEN CANYON S		869.03	960623	1000	275	0.21 *	0.09

<sup>\*</sup> Average of duplicate runs

DEC 0 2 2002

Client: SKYLINE COAL COMPANY

Recvd: 96/02/28 Job#: 818

Final: 96/03/19

Purchase Order:

Contact: Barry Barnum

P.O. Box 719, Helper, UT 84526 CC to Mayo and Associates

Cust LABEL INFO	JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
SKYLINE-S34-12	818.01	951018	1000	275	20.4	0.7
SKYLINE-S15-3	818.02	951018		275 r	17.1	0.6
SKYLINE-S22-11	818.03	951018		275 *	21.6	0.7
SKYLINE-S13-2	818.04	951017		275 *	18.8	0.6
SKYLINE-S17-2	818.05	951017		275 r	1.61	0.09
SKYLINE-S36-12	818.06	951017	1000	275 *	18.1	0.6
SKYLINE-CS-10	818.07	951018	1000	275	15.8	0.5
SKYLINE-CS-9	818.08	951017	1000	275 r	21.8	0.7

<sup>\*</sup> Average of duplicate runs

MOORFUTATED

DEC 0 2 2002

r: Laboratory RERUN in progress as quality control check. Will notify if result differs from ORIGINAL.

Client: MAYO AND ASSOCIATES Purchase Order: 41-7261-6 Recvd: 96/05/31,06/10

Contact: K. Payne, 801/785-2385,-2387(f)
710 E. 100 N., Lindon, UT 84042
FOR: Skyline Coal Co., 801/637-7925 Job# : 848
Final : 96/08/26 LABORATORY RERUNS

Cust LABEL INFO	JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
MAYO-SKY-M1-9L-E1-XC31 1/2	848.01	960508	1000	250 *	0.03	0.09
MAYO-SKY-M1-9L-E2-XC23 1/2	848.02	960508	1000	275 *	0.03	0.09
MAYO-SKY-M3-WM-E1-XC85 1/2	848.05	960508	1000	250 *	0.12	0.09

The RERUNS agreed with the original runs. Above are average values of duplicate runs.

DEC U ? 2002

Client: MAYO AND ASSOCIATES Purchase Order: 41-7261-6

Recvd: 96/05/31,06/10 Contact: K. Payne, 801/785-2385,-2387(f)

Job# : 848 710 E. 100 N., Lindon, UT 84042

Final: 96/07/08 FOR: Skyline Coal Co., 801/637-7925

JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
848.01	960508	1000	275 r	0.16	0.09
848.02	960508	1000	275 r	0.16	0.09
848.03	960508	1000	250 *	0.28	0.09
848.04	960508	1000	215 *	0.26	0.09
848.05	960508	1000	250 *	0.12	0.09
848.06	960606	1000	274	4.56	0.15
848.07	960606	1000	260	2.83	0.10
848.08	960606	1000	275	12.0	0.4
848.09	960605	1000	244 *	13.9	0.5
848.10	960605	1000	275	11.1	0.4
848.11	960606	1000	261	18.4	0.6
848.12	960606	1000	275	15.1	0.5
848.13	960605	1000	275	10.6	0.4
848.14	960522	1000	275	1.73	0.09
	848.01 848.02 848.03 848.04 848.05 848.06 848.07 848.08 848.09 848.10 848.11 848.12 848.13	848.01 960508 848.02 960508 848.03 960508 848.04 960508 848.05 960508 848.06 960606 848.07 960606 848.09 960606 848.09 960605 848.10 960605 848.11 960606 848.12 960606	848.01 960508 1000 848.02 960508 1000 848.03 960508 1000 848.04 960508 1000 848.05 960508 1000 848.06 960606 1000 848.07 960606 1000 848.08 960606 1000 848.09 960605 1000 848.10 960605 1000 848.11 960606 1000 848.12 960606 1000 848.13 960605 1000	848.01 960508 1000 275 r 848.02 960508 1000 275 r 848.03 960508 1000 250 * 848.04 960508 1000 215 * 848.05 960508 1000 250 * 848.06 960606 1000 274 848.07 960606 1000 260 848.08 960606 1000 275 848.09 960605 1000 244 * 848.10 960605 1000 275 848.11 960606 1000 261 848.12 960606 1000 275 848.13 960605 1000 275	848.01       960508       1000       275 r       0.16         848.02       960508       1000       275 r       0.16         848.03       960508       1000       250 *       0.28         848.04       960508       1000       215 *       0.26         848.05       960508       1000       250 *       0.12         848.06       960606       1000       274       4.56         848.07       960606       1000       260       2.83         848.08       960606       1000       275       12.0         848.09       960605       1000       244 *       13.9         848.10       960605       1000       275       11.1         848.11       960606       1000       275       15.1         848.13       960605       1000       275       15.1         848.13       960605       1000       275       10.6

<sup>\*</sup> Average of duplicate runs

INCOM- STATED

DEC 0 2 2007

r RERUN in progress

Recvd: 02/07/08 Contact: E. Petersen, 801/766-4006
Job#: 1626 2695 N. 600 E.

Job# : 1626 2695 N. 600 E. Final : 02/08/05 Skyline Mine Fault Investigation 2002 Lehi, UT 84043

PETERSEN- JC-1 1626.01 020628 1000 27 PETERSEN- James Cyn Well 19 1626.02 020619 1000 27	s tu	eTU
PETERSEN- 10 Left Sump 1626.03 020702 1000 25 PETERSEN- 9 L Horiz Borehole 1626.04 020702 1000 27	5 1.11 3 1.31	0.09 0.09 0.09 0.09

MOUNTARING

DEC 0 2 2002

DIV OF OIL 675 & Action of

Client: PETERSON HYDROLOGIC-SKYLINE Purchase Order: Invoice to C. Hansen Recvd: 02/06/06 Contact: E. Petersen, 801/766-4006

Job# : 1617 2695 N. 600 E.

Final: 02/08/05 Skyline Mine Fault Investigation 2002 Lehi, UT 84043

Cust LABEL INFO	JOB.SX	REFDATE Q	UANT ELY	s TU	eTU
PETERSEN-E.LAKE-1 MID LAKE PETERSEN-E.LAKE-2 NORTH END PETERSEN-J.C.WELL 1 PETERSEN-J.C.WELL 2 PETERSEN-JC-1 14-08	1617.01 1617.02 1617.03 1617.04 1617.05	020524 020524 020524	1000 27 1000 27 1000 27 1000 27 1000 27	5 8.52 5 1.04* 5 1.00*	0.25 0.28 0.09 0.09 0.09

<sup>\*</sup> Average of duplicate runs

INCOMPURATED

DE AN

Recvd: 02/06/06 Contact: E. Petersen, 801/766-4006

Job# : 1617 2695 N. 600 E. Final : 02/06/26 Skyline Mine Fault Investigation 2002 Lehi, UT 84043

Cust LABEL INFO	JOB.SX	REFDATE (		ELYS	TU	eTU
PETERSEN-E.LAKE-1 MID LAKE	1617.01		1000	275	7.67	0.25
PETERSEN-E.LAKE-2 NORTH END	1617.02	020524	1000	275	8.52	0.28
PETERSEN-J.C.WELL 1	1617.03	020524		275	1.00 r	0.09
PETERSEN-J.C.WELL 2 PETERSEN-JC-1 14-08	1617.04	020524	1000	275	0.99 r	0.09
	1617.05	020604	1000	275	0.87 r	0.09

r: Laboratory RERUN in progress

MOUNTED

DEC 0 2 2002

DIV OF OIL GAS & ASSESSED

Client: PETERSON HYDROLOGIC-SKYLINE Purchase Order: Invoice to C. Hansen Recvd: 02/04/22 Contact: E. Petersen, 801/766-4006.

Job# : 1600 2695 N. 600 E.

Final: 02/05/15 Skyline Mine Fault Investigation 2002 Lehi, UT 84043

PETERSEN-9 Left Borehole XC59 1600.01 020410 1000 275 0.16 0.09 PETERSEN-Diagonal Fault 1600.02 020410 1000 275 0.01 0.09 PETERSEN-11 L Hdgate E1XC62 1600.03 020410 1000 275 0.30* 0.09 PETERSEN-E Submains E1XC5 Flt 1600.04 020410 1000 275 0.01* 0.09 PETERSEN-E Submains E3XC14 Flt 1600.05 020410 1000 275 0.89* 0.09 PETERSEN-11 L Hdgate E1XC39 Flt 1600.06 020410 1000 275 0.01 0.09	Cust LABEL INFO	JOB.SX	REFDATE	TNAUQ	ELYS	TU	eTU
- PETERSEN-II DETT	PETERSEN-Diagonal Fault PETERSEN-11 L Hdgate E1XC62 PETERSEN-E Submains E1XC5 Flt PETERSEN-E Submains E3XC14 Flt	1600.02 1600.03 1600.04 1600.05	020410 020410 020410 020410	1000 1000 1000 1000	275 275 275 275	0.01 0.30* 0.01* 0.89*	0.09 0.09 0.09 0.09

<sup>\*</sup> Average of duplicate runs

MOOREGNATED

DEC 6 2 2002

Recvd: 02/07/08 Contact: E. Petersen, 801/766-4006

Job# : 1626 2695 N. 600 E.

Final: 02/08/05 Skyline Mine Fault Investigation 2002 Lehi, UT 84043

Cust LABEL INFO	JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
PETERSEN- JC-1 PETERSEN- James Cyn Well 19 PETERSEN- 10 Left Sump	1626.01 1626.02 1626.03	020628 020619 020702		275 275 253	1.18 1.11 1.31	0.09 0.09 0.09
PETERSEN- 9 L Horiz Borehole	1626.04	020702	1000	275	0.17	0.09

MOONFURATED

DEC 0 2 2002

Recvd: 02/06/06 Contact: E. Petersen, 801/766-4006.

Job# : 1617 26 Final : 02/08/05 Skyline Mine Fault Investigation 2002 Le

2695 N. 600 E. Lehi, UT 84043

Cust LABEL INFO	JOB.SX	REFDATE	TILAUQ	ELYS	TU	eTU
PETERSEN-E.LAKE-1 MID LAKE PETERSEN-E.LAKE-2 NORTH END PETERSEN-J.C.WELL 1 PETERSEN-J.C.WELL 2	1617.01 1617.02 1617.03 1617.04	020524 020524 020524 020524	1000 1000 1000 1000	275 275 275 275	7.67 8.52 1.04* 1.00*	0.25 0.28 0.09 0.09
PETERSEN-JC-1 14-08	1617.05	020604	1000	275	0.96*	0.09

<sup>\*</sup> Average of duplicate runs

INCOM-UTATED

DEC 0 2 2002 DIV OF OIL GAS & MINING

Recvd: 02/07/08 Contact: E. Petersen, 801/766-4006

Job# : 1626 2695 N. 600 E.

Final: 02/08/05 Skyline Mine Fault Investigation 2002 Lehi, UT 84043

Cust LABEL INFO	JOB.SX	REFDATE	-	ELYS	TU	eTU
PETERSEN- JC-1 PETERSEN- James Cyn Well 19	1626.01 1626.02	020628		275 275	1.18	0.09
PETERSEN- 10 Left Sump	1626.02	020702		253	1.31	
PETERSEN- 9 L Horiz Borehole	1626.04	020702	1000	275	0.17	0.09

INCOMPORATED

DEC 0 2 2002

Recvd: 02/06/06 Contact: E. Petersen, 801/766-4006.

Job# : 1617 2695 N. 600 E.

Final: 02/08/05 Skyline Mine Fault Investigation 2002 Lehi, UT 84043

Cust LABEL INFO	JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
PETERSEN-E.LAKE-1 MID LAKE PETERSEN-E.LAKE-2 NORTH END PETERSEN-J.C.WELL 1 PETERSEN-J.C.WELL 2 PETERSEN-JC-1 14-08	1617.01 1617.02 1617.03 1617.04 1617.05	020524 020524 020524 020524 020604	1000 1000 1000 1000	275 275 275 275 275 275	7.67 8.52 1.04* 1.00*	0.25 0.28 0.09 0.09 0.09

<sup>\*</sup> Average of duplicate runs

MOCA-URATED

**DEC** 0 2 2002

Client: CANYON FUEL COMPANY-E. PETERSEN

Purchase Order:

Recvd: 01/05/10 Contact: Erik Petersen, 801/766-4006

Job# : 1491 Petersen Hyd Final : 01/06/26 Ref: In-mine GW age dating 2001

Petersen Hydrologic, 2695 N. 600 E. dating 2001 Lehi, Utah 84043

Cust LABEL INFO	JOB.SX	REFDATE	TMAUQ	ELYS	TU	eTU
SKYLINE MINE-16L XC12	1491.01	010418	1000	251	-0.02	0.09
SKYLINE MINE-14L E1 XC36	1491.02	010418	1000	250	0.12	0.09
SKYLINE MINE-9LE3XC40 borehole	1491.03	010419	1000	243	0.06*	0.09
SKYLINE MINE-Diag Submn E3 XC12	1491.04	010419	1000	252	0.05	0.09
SKYLINE MINE-8LE3XC62 borehole	1491.05	010418	1000	250	0.78*	0.10
SKYLINE MINE-8L Bleeder XC51 bh	1491.06	010418	1000	251	0.51*	0.09
SKYLINE MINE-8LE2XC62 bh (uncas)	1491 07	010418	1000	251	0.06	0.00

<sup>\*</sup> Average of duplicate runs

INCOMPORATED

DEC 0 3 2002

Recvd: 02/06/06 Contact: E. Petersen, 801/766-4006

Job# : 1617 2695 N. 600 E.

Final: 02/06/26 Skyline Mine Fault Investigation 2002 Lehi, UT 84043

Cust LABEL INFO	JOB.SX	REFDATE QU	JANT ELYS	TU	eTU
PETERSEN-E.LAKE-1 MID LAKE PETERSEN-E.LAKE-2 NORTH END	1617.01 1617.02	020524 1	L000 275	7.67 8.52	0.25
PETERSEN-J.C.WELL 1 PETERSEN-J.C.WELL 2	1617.03 1617.04	020524 1	1000 275 1000 275	1.00 r 0.99 r	0.09
PETERSEN-JC-1 14-08	1617.05		1000 275	0.87 r	

r: Laboratory RERUN in progress

INCOMPUTATED

DEC II > 21

DIV OF OIL GAS & MARKING

Client: PETERSON HYDROLOGIC-SKYLINE Purchase Order: Invoice to C. Hansen Recvd: 02/04/22 Contact: E. Petersen, 801/766-4006.

Job# : 1600 Final : 02/05/15 Skyline Mine Fault Investigation 2002 2695 N. 600 E. Lehi, UT 84043

Cust LABEL INFO	JOB.SX	REFDATE	TMAUQ	ELYS	TU	eTU
PETERSEN-9 Left Borehole XC59	1600.01	020410	1000	275	0.16	0.09
PETERSEN-Diagonal Fault	1600.02	020410	1000	275	0.01	0.09
PETERSEN-11 L Hdgate E1XC62	1600.03	020410	1000	275	0.30*	0.09
PETERSEN-E Submains E1XC5 Flt	1600.04	020410	1000	275	0.01*	0.09
PETERSEN-E Submains E3XC14 Flt	1600.05	020410	1000	275	0.89*	0.09
PETERSEN-11 L Hdgate E1XC39 Flt	1600.06	020410	1000	275	0.01	0.09
PETERSEN-11 Left	1600.07	020425	1000	275	0.06	0.09

<sup>\*</sup> Average of duplicate runs

MOURFURATED

DEC 0 2 2002

Propose described

Client: PETERSON HYDROLOGIC - SKYLINE MINE Purchase Order: NONE Contact: E. Petersen, 801/766-4006 Recvd : 01/10/08

Job# : 1543 2695 N. 600 E.

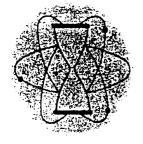
Final: 01/10/30 Inv. to Chris Hansen, Canyon Fuel Co. Lehi, UT 84043

Cust LABEL INFO		REFDATE	-		TU	eTU
PETERSEN - Well JC-1 PETERSEN - Electric Lake	1543.01	010926	1000	275	0.24* 12.6 *	0.09

<sup>\*</sup> Average of duplicate runs

INCORPURATED

DEC 0 2 2002



as of January 1, 1993 New Address 711 Concord Avenue Cambridge, MA 02138 Telephone/Telefax Numbers remain the same DEC U 2 2007

# KRUEGER ENTERPRISES, INC. DIV OF OIL GAS & MINING

GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET . CAMBRIDGE, MASSACHUSETTS 02139 . (617) 876-3691

### STABLE ISOTOPE RATIO ANALYSES

#### REPORT OF ANALYTICAL WORK

Submitted by:

Erik C. Petersen

Mayo and Associates

P.O. Box 1960

Orem, UT 84059

Date Received:

Date Reported:

Your Reference:

02/02/94

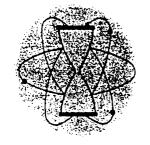
02/25/94

Skyline samples

Our Lab. Number	Your Sample Number	Description	δ <sup>13</sup> C*
CR-78662	1-07F	Carbonate	- 7.7
CR-78663	1-08F	Carbonate	- 7.3
CR-78664	1-09F	Carbonate	- 6.7
CR-78665	1-10F	Carbonate	- 3.9
CR-78666	1-11F	Carbonate	- 8.6
CR-78667	1-12F	Carbonate	- 1.2
CR-78668	1-13F	Carbonate	- 1.9
CR-78669	1-14F	Carbonate	- 6.2
CR-78670	1-15F	Carbonate	- 1.5
CR-78671	1-16F	Carbonate	- 0.3
CR-78672	1-17F	Carbonate	- 0.7

$$\delta^{13}C_{\text{sample}} = \begin{bmatrix} \frac{13C/^{12}C_{\text{sample}}}{13C/^{12}C_{\text{standard}}} & -1 \\ \end{bmatrix} \times 1000.$$

<sup>\*</sup>Unless otherwise noted, analyses are reported in % notation and are computed as follows:



DEC 0 2 2007 Numbers

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Numbers

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# KRUEGER ENTERPRISES, INC. DIV OF OIL GAS & MINING

#### GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET . CAMBRIDGE, MASSACHUSETTS 02139 . (617) 876-3691

### STABLE ISOTOPE RATIO ANALYSES

### REPORT OF ANALYTICAL WORK

Submitted by:

Erik C. Petersen Mayo and Associates P.O. Box 1960 Orem, UT 84059 Date Received:

Date Reported:

02/02/94

Your Reference:

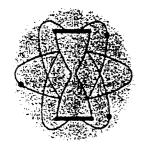
Skyline samples

Our Lab. Number	Your Sample Number	Description	δ <sup>13</sup> C*
CR-78673	1-18F	Carbonate	- 3.1
CR-78674	1-19F	Carbonate	- 3.6
CR-78675	1-20F	Carbonate	- 1.6
CR-78676	1-21F	Carbonate	- 9.6
CR-78677	1-22F	Carbonate	-10.7 -10.5 **
CR-78678	1-23F	Carbonate	-10.3
CR-78679	1-24F	Carbonate	-10.2
CR-78680	3-01D	Carbonate	- 8.6
CR-78681	3-04D	Carbonate	- 6.5
CR-78682	3-05D	Carbonate	- 1.5
CR-78683	3-06D	Carbonate	- 7.3

<sup>\*\*</sup> Duplicate preparations and analyses.

$$\delta^{13}C_{\text{sample}} = \begin{bmatrix} \frac{13C/^{12}C_{\text{sample}}}{13C/^{12}C_{\text{slandard}}} - 1 \end{bmatrix} \times 1000$$

<sup>\*</sup>Unless otherwise noted, analyses are reported in \*L notation and are computed as follows:



# KRUEGER ENTERPRISES, INC.

GEOCHRON LABORATORIES DIVISION

DIV OF OIL GAS & MINING

24 BLACKSTONE STREET . CAMBRIDGE, MASSACHUSETTS 02139 . (617) 876-3691

#### STABLE ISOTOPE RATIO ANALYSES

#### REPORT OF ANALYTICAL WORK

Submitted by:

Erik C. Petersen Mayo and Associates

P.O. Box 1960 Orem, UT 84059 Date Received: Date Reported:

Your Reference:

02/02/94 02/25/94

Skyline samples

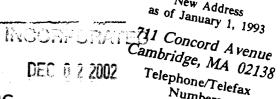
Our Lab. Number	Your Sample Number	Description	δ <sup>13</sup> C*
CR-78684	3 <b>-</b> 02S	Carbonate	-10.0
CR-78685	3-01F	Carbonate	- 2.8
CR-78686	3-02F	Carbonate	-13.6 -13.5 **
CR-78687	3-03F	Carbonate	-12.8
CR-78688	3-04F	Carbonate	-14.7
CR-78689	3-05F	Carbonate	-14.9
CR-78690	3-06F	Carbonate	-13.8
CR-78691	3-07F	Carbonate	-13.4
CR-78692	3-08F	Carbonate	- 9.5
CR-78693	3-09F	Carbonate	-14.4
CR-78694	CS-12(M)	Carbonate	-12.9

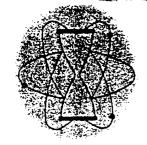
<sup>\*\*</sup> Duplicate preparations and analyses.

$$\delta^{13}C_{\text{sample}} = \begin{bmatrix} \frac{^{13}C/^{12}C_{\text{sample}}}{^{13}C/^{12}C_{\text{slandard}}} - 1 \\ \end{bmatrix} \times 1000$$

Where:

<sup>\*</sup>Unless otherwise noted, analyses are reported in \*L notation and are computed as follows:





Numbers KRUEGER ENTERPRISES, IN STY OF OIL GAS & MINING Temain the same

#### GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET . CAMBRIDGE, MASSACHUSETTS 02139 . (617) 876-3691

### STABLE ISOTOPE RATIO ANALYSES

### REPORT OF ANALYTICAL WORK

Submitted by:

Erik C. Petersen Mayo and Associates P.O. Box 1960

Orem, UT 84059

Date Received:

Date Reported:

Your Reference:

02/02/94

02/25/94

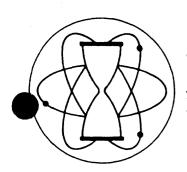
Skyline samples

Our Lab. Number	Your Sample Number	Description	δ <sup>13</sup> C•
CR-78651	1-01D	Carbonate	- 8.4
CR-78652	1-02D	Carbonate	- 2.1
CR-78653	1 – 1 1D	Carbonate	-10.3
CR-78654	1-12D	Carbonate	-9.4 -9.4 **
CR-78655	1-028	Carbonate	-11.1
CR-78656	1-01F	Carbonate	- 1.2
CR-78657	1-02F	Carbonate	- 3.7
CR-78658	1-03F	Carbonate	-5.7 -5.8 **
CR-78659	1-04F	Carbonate	- 8.1
CR-78660	1-05F	Carbonate	- 6.3
CR-78661	1-06F	Carbonate	-0.8 - 0.7 **

<sup>\*\*</sup> Duplicate preparations and analyses.

$$\delta^{13}C_{\text{sample}} = \begin{bmatrix} \frac{13}{13}C/^{12}C_{\text{sample}} & -1 \\ \frac{13}{13}C/^{12}C_{\text{standard}} \end{bmatrix} \times 1000$$

<sup>\*</sup>Unless otherwise noted, analyses are reported in \*L notation and are computed as follows:



711 CONCORD AVENUE + CAMBRIDGE, MASSACHUSETTS 02138 + U.S.A

TELEPHONE: (617) 876-3691 TELEFAX: (617) 661-0148

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DEC 8 2 2007

DIV OF OIL GAS & MINING

#### STABLE ISOTOPE RATIO ANALYSES

#### REPORT OF ANALYTICAL WORK

Submitted by:

Kelly Payne

Mayo and Associates 710 East 100 North Lindon, UT 84042 Date Received:

06/11/96

Date Reported:

06/28/96

Your Reference:

Letter of

8 June 96

Skyline Samples

Our Lab. Number	Your Sample Number	Description	δ <sup>13</sup> C*
CR-90191	WQ-1-39	BaCO3	-15.0
CR-90195	WQ-3-43	BaCO3	-12.7
CR-90197	WQ-2-15	BaCO3	-12.6 -12.3 **

\*\* Duplicate preparations and analyses.

$$\delta^{13}C_{\text{sample}} = \begin{bmatrix} \frac{13C/^{12}C_{\text{sample}}}{13C/^{12}C_{\text{standard}}} & -1 \end{bmatrix} \times 1000$$

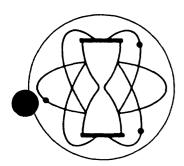
Where:

And:

<sup>13</sup>C/<sup>12</sup>C standard is PDB

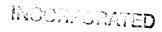
 $^{13}C/^{12}C$  standard = 0.011237

<sup>\*</sup>Unless otherwise noted, analyses are reported in \*L notation and are computed as follows:



711 CONCORD AVENUE + CAMBRIDGE, MASSACHUSETTS 02138 + U.S.A

TELEPHONE: (617) 876-3691 TELEFAX: (617) 661-0148



**DEC 0 2 2002** 

DIV OF OIL GAS & MINING

### STABLE ISOTOPE RATIO ANALYSES

REPORT OF ANALYTICAL WORK

Submitted by:

Kelly Payne

Mayo and Associates

710 East 100 North

Lindon, UT 84042

Date Received:

02/15/96

Date Reported:

02/27/96

Your Reference:

Letter of Feb. 6

Skyline

Our Lab. Number	Your Sample Number	Description	δ <sup>13</sup> C•
CR-88846	\$22-5	Carbonate	-12.1
CR-88850	S14-4	Carbonate	-13.1
CR-88851	S35-8	Carbonate	-10.8 -10.8 **
CR-88852	S26-13	Carbonate	-13.3

<sup>\*\*</sup> Duplicate preparations and analyses.

$$\delta^{13}C_{\text{sample}} = \begin{bmatrix} \frac{13C/12C_{\text{sample}}}{13C/12C_{\text{standard}}} & -1 \end{bmatrix} \times 1000$$

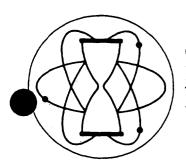
Where:

And:

13C/12C standard is PDB

 $^{13}C/^{12}C$  standard = 0.011237

<sup>\*</sup>Unless otherwise noted, analyses are reported in \* notation and are computed as follows:



711 CONCORD AVENUE + CAMBRIDGE, MASSACHUSETTS 02138 + U.S.A TELEPHONE: (617) 876-3691 TELEFAX: (617) 661-0148

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DIV OF OIL GAS & MINING

#### STABLE ISOTOPE RATIO ANALYSES

#### REPORT OF ANALYTICAL WORK

Submitted by:

Travis L. Jensen

Mayo and Associates 710 East 100 North Lindon, UT 84042

Date Received:

12/28/98

Date Reported:

03/11/99

Your Reference:

Skyline Mine

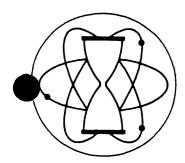
Our Lab. Number	Your Sample Number	Description	δ <sup>34</sup> S*
SR-99388	M1SSM E1 C102	BaSOц	+14.6 +14.0 **

Duplicate analyses on separate aliquots of the original sample.

\*Unless otherwise noted, analyses are reported in 1/2 notation and are computed as follows:

$$\delta^{34} S_{\text{sample}} = \begin{bmatrix} \frac{34 S/32 S_{\text{sample}}}{34 S/32 S_{\text{standard}}} & -1 \end{bmatrix} \times 1000$$

Where:



711 CONCORD AVENUE + CAMBRIDGE, MASSACHUSETTS 02138 + U.S.A TELEPHONE: (617) 876-3691 TELEFAX: (617) 661-0148

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DEC 11 / 2011

DIV OF OIL GAS & MINING

### STABLE ISOTOPE RATIO ANALYSES

REPORT OF ANALYTICAL WORK

Travis L. Jensen Submitted by:

> Mayo and Associates 710 East 100 North Lindon, UT 84042

01/15/99 Date Received: 03/11/99

Date Reported:

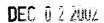
Skyline Mine Your Reference:

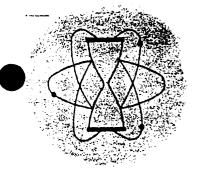
Our Lab. Number	Your Sample Number	Description	δ <sup>34</sup> S*
SR-99639	5LTG E1 C39	BaSO <sub>4</sub>	+20.6

\*Unless otherwise noted, analyses are reported in % notation and are computed as follows:

Where:







# KRUEGER ENTERPRISES, INC.

DIV OF OIL GAS & MINING

GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

#### STABLE ISOTOPE RATIO ANALYSES

### REPORT OF ANALYTICAL WORK

Submitted by:

Erik C. Petersen

Mayo and Associates

P.O. Box 1960 Orem, UT 84059 Date Received: 02/02/94

Date Reported:

04/07/94

Your Reference:

Skyline samples

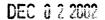
Our Lab. Number	Your Sample Number	Description	δ <sup>34</sup> S*
SR-78684	3 <b>-</b> 02S	Sulfate	+16.8
SR-78685	3-01F	Sulfate	+ 7.2
SR-78686	3-02F	Sulfate	+ 6.8 + 6.8 **
SR-78687	3-03F	Sulfate	+ 5.5
SR-78688	3-04F	Sulfate	+ 7.7
SR-78689	3-05F	Sulfate	+ 6.8
SR-78690	3-06F	Sulfate	+ 6.7
SR-78691	3-07F	Sulfate	+ 5.7
SR-78692	3-08F	Sulfate	+ 9.5
SR-78693	3-09F	Sulfate	+ 6.0
SR-78694	CS-12(M)	Sulfate	+ 7.2

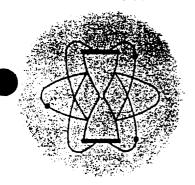
### \*\* Duplicate preparations and analyses

$$\delta^{34} S_{\text{sample}} = \begin{bmatrix} \frac{34}{5} S_{\text{sample}} \\ \frac{34}{5} S_{\text{standard}} \end{bmatrix} \times 1000$$

<sup>\*</sup>Unless otherwise noted, analyses are reported in % notation and are computed as follows:







# KRUEGER ENTERPRISES, INC.

DIV OF OIL GAS & MINING

GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

### STABLE ISOTOPE RATIO ANALYSES

#### REPORT OF ANALYTICAL WORK

Submitted by:

Erik C. Petersen

Mayo and Associates

P.O. Box 1960 Orem, UT 84059 Date Received: 02

02/02/94

Date Reported:

04/07/94

Your Reference:

Skyline samples

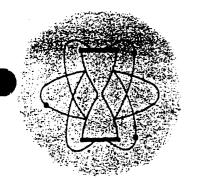
_	8 <sup>34</sup> S*	Description	Your Sample Number	Our Lab. Number
	8-5-	Description	Number	·
	+ 4.2	Sulfate	1-18F	SR-78673
	+ 6.7	Sulfate	1-19F	SR-78674
	+ 5.0	Sulfate	1-20F	SR-78675
) <b>*</b> *	+15.4 +15.9	Sulfate	1-21F	SR-78676
	+19.7	Sulfate	1-22F	SR-78677
	+17.1	Sulfate	1-23F	SR-78678
	+17.6	Sulfate	1-24F	SR-78679
	+ 8.9	Sulfate	3-01D	SR-78680
analysis	Insufficient sulfate for	Sulfate	3-04D	SR-78681
analysis	Insufficient sulfate for	Sulfate	3-05D	SR-78682
analysis	Insufficient sulfate for	Sulfate	3-06D	SR-78683

## \*\* Duplicate preparations and analyses

$$\delta^{34} S_{\text{sample}} = \left[ \frac{3^4 S/^{32} S_{\text{sample}}}{3^4 S/^{32} S_{\text{standard}}} - 1 \right] \times 1000$$

Where:

<sup>\*</sup>Unless otherwise noted, analyses are reported in 14 notation and are computed as follows:



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# KRUEGER ENTERPRISES, INC.

GEOCHRON LABORATORIES DIVISION

DIV OF OIL GAS & MINING

24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

### STABLE ISOTOPE RATIO ANALYSES

#### REPORT OF ANALYTICAL WORK

Submitted by:

Erik C. Petersen

Mayo and Associates

P.O. Box 1960 Orem, UT 84059 Date Received:

02/02/94

Date Reported:

04/07/94

Your Reference:

Skyline samples

Our Lab. Number	Your Sample Number	Description	δ <sup>34</sup> S•
- Total of	·	- Coordinates	
SR-78662	1-07F	Sulfate	+16.8
SR-78663	1-08F	Sulfate	+ 7.7
SR-78664	1-09F	Sulfate	+ 8.0
SR-78665	1-10F	Sulfate	+ 4.5
SR-78666	1-11F	Sulfate	+ 5.3 + 5.4 **
SR-78667	1-12F	Sulfate	+ 4.6
SR-78668	1-13F	Sulfate	+ 3.4
SR-78669	1-14F	Sulfate	+ 12.1
SR-78670	1-15F	Sulfate	+ 3.3
SR-78671	1-16F	Sulfate	+ 5.2
SR-78672	1-17F	Sulfate	+ 5.2
** Duplio	cate preparatio	ns and analyses.	

<sup>\*</sup>Unless otherwise noted, analyses are reported in  $\Sigma$  notation and are computed as follows:

$$\delta^{34}S_{\text{sample}}\mathcal{I}_{\text{a}} = \begin{bmatrix} \frac{34}{3}S/32S_{\text{sample}} \\ \frac{34}{3}S/32S_{\text{standard}} \end{bmatrix} \times 1000$$

Where:





## DEC 0 2 2002

DIV OF OIL GAS & MINING

## KRUEGER ENTERPRISES, INC.

GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

#### STABLE ISOTOPE RATIO ANALYSES

#### REPORT OF ANALYTICAL WORK

Submitted by:

Erik C. Petersen

Mayo and Associates

P.O. Box 1960

Orem, UT 84059

Date Received:

02/02/94

Date Reported:

04/07/94

Your Reference:

Skyline samples

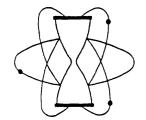
Our Lab. Number	Your Sample Number	Description	δ <sup>34</sup> S*
SR-78651	1-01D	Sulfate	+ 6.7
SR-78652	1-02D	Sulfate	+ 6.2
SR-78653	1-11D	Sulfate	+17.2
SR-78654	1-12D	Sulfate	+16.6
SR-78655	1-028	Sulfate	+19.3
SR-78656	1-01F	Sulfate	+ 5.8 + 5.7 **
SR-78657	1-02F	Sulfate	+ 5.9
SR-78658	1-03F	Sulfate	+ 6.4
SR-78659	1-04F	Sulfate	+18.6
SR-78660	1-05F	Sulfate	+ 6.7
SR-78661	1-06F	Sulfate	+ 5.2

# \*\* Duplicate preparations and analyses.

$$\delta^{34} S_{\text{sample}} = \begin{bmatrix} \frac{34}{3^{4}} S_{\text{sample}} & -1 \\ \frac{34}{3^{4}} S_{\text{standard}} & -1 \end{bmatrix} \times 1000$$

Where:

<sup>\*</sup>Unless otherwise noted, analyses are reported in  $\mbox{$\mbox{$\mbox{$\sim$}$}$}$  notation and are computed as follows:



as of January 1, 1993 Telephone To 12138 Telephone/Telefax Numbers PNCFOIL GAS & MINING

New Address

# KRUEGER ENTERPRISES.

GEOCHRON LABORATORIES DIVISION

24 BLACKSTONE STREET • CAMBRIDGE, MASSACHUSETTS 02139 • (617) 876-3691

## STABLE ISOTOPE RATIO ANALYSES

#### REPORT OF ANALYTICAL WORK

Submitted by:

Erik C. Petersen

Mayo and Associates

P.O. Box 1960 Orem, UT 84059 Date Received:

10/12/93

Date Reported:

12/31/93

Your Reference:

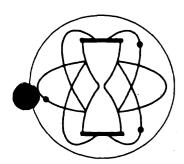
Skyline samples

Our Lab. Number	Your Sample Number	Description	δ <sup>34</sup> S*
SR-77394	#1 WM6 C94 1-03 b	Sulfate	+16.2 +16.5 **
SR-77395	#3 WM1 C863-07 D	Sulfate	+19.4

\*\* Duplicate preparations and analyses.

$$\delta^{34} S_{\text{sample}} = \begin{bmatrix} \frac{34}{3} S_{\text{sample}} \\ \frac{34}{3} S_{\text{standard}} \end{bmatrix} \times 1000$$

<sup>\*</sup>Unless otherwise noted, analyses are reported in % notation and are computed as follows:



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DIV OF OIL GAS & MINING

711 CONCORD AVENUE + CAMBRIDGE, MASSACHUSETTS 02138 + U.S.A TELEPHONE: (617) 876-3691 TELEFAX: (617) 661-0148

#### STABLE ISOTOPE RATIO ANALYSES

#### REPORT OF ANALYTICAL WORK

Submitted by:

Shane Bloomfield Mayo and Associates 710 East 100 North Lindon, UT 84042 Date Received:

04/14/99

Date Reported:

07/19/99

Your Reference:

Willow Creek

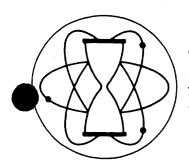
Our Lab. Number	Your Sample Number	Description	δ <sup>34</sup> S* 、
SR-100427	14LHGE1C37 Rib wate 04/12/99	r BaSOц	+18.6 +18.6 **

\*\* Duplicate analyses on separate aliquots of the original sample.

\*Unless otherwise noted, analyses are reported in ‰ notation and are computed as follows:

$$\delta^{34} S_{\text{sample}}^{34} = \begin{bmatrix} \frac{3^4 S/^{32} S_{\text{sample}}}{3^4 S/^{32} S_{\text{standard}}} & -1 \\ \end{bmatrix} \times 1000$$

Where:



711 CONCORD AVENUE + CAMBRIDGE, MASSACHUSETTS 02138 + U.S.A TELEPHONE: (617) 876-3691 TELEFAX: (617) 661-0148

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DIV OF OIL GAS & MINING

#### STABLE ISOTOPE RATIO ANALYSES

#### REPORT OF ANALYTICAL WORK

Submitted by:

Erik C. Petersen

Mayo and Associates 710 East 100 North Lindon, UT 84042

Date Received:

03/24/99

Date Reported:

07/19/99

Your Reference:

Skyline Mine

Our Lab. Number	Your Sample Number	Description	δ <sup>34</sup> S*
SR-100269	14L HG E1 C35 Floor Mar. 22, 1999	BaSO <sub>4</sub>	+18.9
SR-100270	14L HG E1 C35 Roof Mar. 22, 1999	BaSO <sub>4</sub>	+20.3 +20.2 **

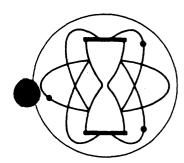
\*\* Duplicate analyses on separate aliquots of the original sample.

$$\delta^{34}S_{\text{sample}} = \begin{bmatrix} \frac{34}{34}S_{\text{sample}} \\ \frac{34}{34}S_{\text{standard}} \end{bmatrix} \times 1000$$

Where:

<sup>\*</sup>Unless otherwise noted, analyses are reported in ‰ notation and are computed as follows:





DEC 0 2 2002

DIV OF OIL GAS & MINING

711 CONCORD AVENUE + CAMBRIDGE, MASSACHUSETTS 02138 + U.S.A TELEPHONE: (617) 876-3691 TELEFAX: (617) 661-0148

#### STABLE ISOTOPE RATIO ANALYSES

#### REPORT OF ANALYTICAL WORK

Submitted by:

Kelly Payne

Mayo and Associates 710 East 100 North Lindon, UT 84042 Date Received: 05/31/96

Date Reported: 06

06/19/96

Your Reference:

Letter of

29 MAY 96

Skyline Samples

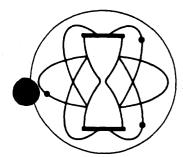
Our Lab. Number	Your Sample Number	Description	δ <sup>34</sup> S*
SR-90129	SKY 3 MI	- 9L-E1-XC3112 BaSO4	+13.9
SR-90130	SKY 4 MI	-9L-EZ-XC2312 BaSO4	+15.5
SR-90131	SKY 7 M3	- 1L-TG-XC27 BaSO4	+14.8 +14.8 **

\*\* Duplicate preparations and analyses.

$$\delta^{34} S_{\text{sample}} = \begin{bmatrix} \frac{3^4 S}{3^2 S_{\text{sample}}} & -1 \\ \frac{3^4 S}{3^2 S_{\text{standard}}} & -1 \end{bmatrix} \times 1000$$

<sup>\*</sup>Unless otherwise noted, analyses are reported in ‰ notation and are computed as follows:





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DIV OF OIL GAS & MINING

711 CONCORD AVENUE + CAMBRIDGE, MASSACHUSETTS 02138 + U.S.A TELEPHONE: (617) 876-3691 TELEFAX: (617) 661-0148

#### STABLE ISOTOPE RATIO ANALYSES

### REPORT OF ANALYTICAL WORK

Submitted by:

Kelly Payne

Mayo and Associates 710 East 100 North Lindon, UT 84042

Date Received:

06/11/96

Date Reported:

07/17/96

Your Reference:

Letter of

8 June 96

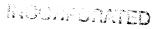
Skyline Samples

Our Lab. Number	Your Sample Number	Description	δ <sup>34</sup> S*
SR-90189	Well #1	Dissolved Sulfate	+ 5.5
SR-90190	Well #2	Dissolved Sulfate	- 0.1
SR-90191	WQ-1-39	Dissolved Sulfate	+12.1
SR-90192	WQ-3-6	Dissolved Sulfate	+5.7 +5.7 *
SR-90193	WQ-3-26	Dissolved Sulfate	+ 8.1
SR-90194	WQ-3-41	Dissolved Sulfate	+13.5
SR-90195	WQ-3-43	Dissolved Sulfate	+10.4
SR-90196	WQ-4-12	Dissolved Sulfate	+11.3
SR-90197	WQ-2-15	Dissolved Sulfate	+ 8.5

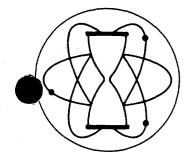
\*\* Duplicate preparations and analyses.

$$\delta^{34}S_{\text{sample}} = \begin{bmatrix} \frac{3^4S}{3^2S_{\text{sample}}} & -1 \\ \frac{3^4S}{3^2S_{\text{standard}}} & -1 \end{bmatrix} \times 1000$$

<sup>\*</sup>Unless otherwise noted, analyses are reported in  $\mbox{\ensuremath{\mbox{$\mbox{$\omega$}}}}$  notation and are computed as follows:







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#### STABLE ISOTOPE RATIO ANALYSES

#### REPORT OF ANALYTICAL WORK

Submitted by:

Kelly Payne

Mayo and Associates 710 East 100 North Lindon, UT 84042

Date Received:

07/29/96

Date Reported:

08/22/96

Your Reference:

Letter of

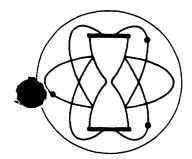
July 26, 1996 Skyline Samples

Our Lab. Number	Your Sample Number	Description		δ <sup>34</sup> S*	
SR-90576	Alpine Well	ВаЅОц		+12.7	
SR-90577	Spring G-37	BaSOц	+19.2	+19.7	**
SR-90578	Green Canyon Spring	BaSO <sub>4</sub>		-0.7	

\*\* Duplicate preparations and analyses.

\*Unless otherwise noted, analyses are reported in ‰ notation and are computed as follows:

$$\delta^{34} S_{\text{sample}} = \left[ \frac{3^4 S/^{32} S_{\text{sample}}}{3^4 S/^{32} S_{\text{standard}}} -1 \right] \times 1000$$



MOONFURATED

DEC @ 2 2002

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#### STABLE ISOTOPE RATIO ANALYSES

#### REPORT OF ANALYTICAL WORK

Submitted by:

Kelly Payne

Mayo and Associates 710 East 100 North Lindon, UT 84042

Date Received: 02/15/96

Date Reported: 03/14/96

Your Reference: Lett

Letter of Feb. 6

Skyline

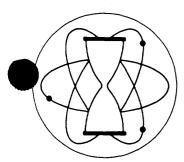
Our Lab. Number	Your Sample Number	Description	δ <sup>34</sup> S*
SR-88846	S22-5	Sulfate	+10.6
SR-88847	S34 <b>-</b> 12	Sulfate	+ 9.1
SR-88848	S15-3	Sulfate	+16.5
SR-88849	S22-11	Sulfate	+ 5.1
SR-88850	S14-4	Sulfate	+14.8 +14.7 **
SR-88851	S35-8	Sulfate	+12.9
SR-88852	S26-13	Sulfate	+ 8.9
SR-88853	S13-2	Sulfate	+10.4
SR-88854	S17-2	Sulfate	- 1.5
SR-88855	S36-12	Sulfate	+10.6

<sup>\*\*</sup> Duplicate preparations and analyses.

$$\delta^{34}S_{\text{sample}} = \begin{bmatrix} \frac{34}{34}S_{\text{sample}} \\ \frac{34}{34}S_{\text{standard}} \end{bmatrix} \times 1000$$

Where:

<sup>\*</sup>Unless otherwise noted, analyses are reported in ‰ notation and are computed as follows:



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-30057

Date Received:

02/06/2003

Your Reference:

Chris Hansen, Canyon Fuel Company

Date Reported:

02/25/2003

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

11 Left Tailgate Bleeder 1 Notch 13 Dec 2002

AGE =

 $29.12 \pm 1.82$  % of the modern (1950) <sup>14</sup>C activity

Description:

Sample of barium carbonate

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

Comments:

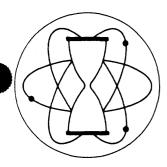
 $\delta^{13}C_{PDB} =$ 

-10.8 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-30056

Date Received:

02/06/2003

Your Reference:

Chris Hansen, Canyon Fuel Company

Date Reported:

02/25/2003

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

East Submains E1 XC5 13 Dec 2002

AGE =

 $16.73 \pm 1.70$  % of the modern (1950) <sup>14</sup>C activity

Description:

Sample of barium carbonate

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

Comments:

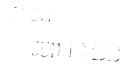
 $\delta^{13}C_{PDB} =$ 

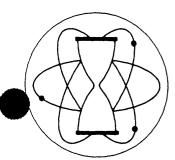
-10.7 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.





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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-30055

Date Received:

02/06/2003

Your Reference:

Chris Hansen, Canyon Fuel Company

Date Reported:

02/25/2003

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

12 Left A Borehole 13 Dec 2002

AGE =

 $10.97 \pm 1.64 \%$  of the modern (1950) <sup>14</sup>C activity

escription:

Sample of barium carbonate

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

Comments:

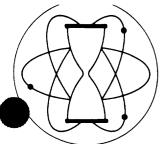
 $\delta^{13}C_{PDB} =$ 

-10.8 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.



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RADIOCARBON AGE DETERMINATION

REPORT OF ANALYTICAL WORK

Our Sample No.

GX-30054

Date Received:

02/06/2003

Your Reference:

Chris Hansen, Canyon Fuel Company

Date Reported:

02/25/2003

Submitted by:

Mr. Erik C. Petersen Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043

Sample Name:

JC-1 Outlet at Huntington Creek 7 Jan 2003

AGE =

 $27.58 \pm 1.87$  % of the modern (1950) <sup>14</sup>C activity

escription:

Sample of barium carbonate

Pretreatment:

The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis.

<sup>13</sup>C analysis was made from a small portion of the same evolved gas.

Comments:

 $\delta^{13}C_{PDB} =$ 

-11.0 %

Notes:

This date is based upon the Libby half life (5570 years) for <sup>14</sup>C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

Client: PETERSON HYDROLOGIC-UTAH POWER

Recvd : 03/01/17

Job# : 1708

Final : 03/02/16

Purchase Order: 3000015409

Contact: E. Petersen, 801/766-4006

2695 N. 600 E.; Lehi, UT 84043

Results to Petersen - (UTAH POWER)

Cust LABEL INFO		REFDATE		TU	eTU
PETERSEN- JC-1 PETERSEN-JC-1 OUT HUNT. CREEK PETERSEN-JC-1 OUT HUNT. CREEK	1708.01 1708.02	030114	255 274 275	1.77 1.94 1.85 r	0.09

r: RERUN in progress

Client: PETERSON HYDROLOGIC-UTAH POWER

Purchase Order: 3000015409 Recvd : 02/12/16 Contact: E. Petersen, 801/766-4006

Job# : 1699 2695 N. 600 E.; Lehi, UT 84043 Final : 03/02/16 Results to Petersen - (UTAH POWER)

Cust LABEL INF	O JOB.SX	REFDATE QUANT	ELYS	TU	eTU
UTAH POWER-JC-1 UTAH POWER-JC-1 UTAH POWER-JC-1 UTAH POWER-JC-1	21 1699.02 29 1699.03	021002 1000 021021 1000 021029 1000 021202 1000	275 275 275 275	2.22 1.44* 2.06 1.87	0.10 0.09 0.09 0.09

<sup>\*</sup> Average of duplicate runs

Client: PETERSEN HYDROLOGIC-SKYLINE Purchase Order: Bill to: C. Hansen Recvd: 03/03/05 Contact: E. Petersen, 801/766-4006 Job#: 1728 2695 N. 600 E.

Final: 03/03/25 SKYLINE MINE FAULT INVESTIGATION 2003

Lehi, UT 84043

Cust LABEL INFO JOB.SX REFDATE QUANT ELYS TU eTU

PETERSEN-JC-1 1728.01 030228 1000 275 1.71 0.09

Client: PETERSON HYDROLOGIC-SKYLINE Purchase Order: Bill to: C. Hansen

Recvd: 03/02/20 Contact: E. Petersen, 801/766-4006

Job# : 1724 2695 N. 600 E. Final : 03/03/25 SKYLINE MINE Lehi, UT 84043

Cust LABEL INFO		REFDATE (	-	ELYS	TU	eTU
PETERSEN-11 LEFT BLEEDER PETERSEN-E SUBMAINS E1 XC5 FLT. PETERSEN-12 LEFT A BOREHOLE 2 PETERSEN-10 LEFT ENTRY 1	1724.01	030213 030213		251 275 275 250	0.71 r 0.16*r 0.15*r	0.09

<sup>\*</sup> Average of duplicate runs

r RERUN in progress

Client: PETERSEN HYDROLOGIC-UTAH POWER Purchase Order: 3000015409

Recvd: 03/02/06 Contact: E. Petersen, 801/766-4006

Job# : 1720 2695 N. 600 E.; Lehi, UT 84043

Final: 03/03/25 Skyline Mine Results to Petersen - (UTAH POWER)

Cust LABEL INFO JOB.SX REFDATE QUANT ELYS TU eTU

PETERSEN-JC-1 1720.01 030131 1000 275 1.80 0.09

e de la Colonia. Alaman e de mando Client: PETERSEN HYDROLOGIC-SKYLINE Purchase Order: Bill to: C. Hansen Recvd: 02/10/07 Contact: E. Petersen, 801/766-4006

Job# : 1673 2695 N. 600 E.

Final: 03/03/24 LABORATORY RERUNS SKYLINE MINE, 2002 Lehi, UT 84043

Cust LABEL INFO	JOB.SX	REFDATE QUANT	ELYS	TU	eTU
SKYLINE-10 Left Entry 1 SKYLINE-10 Left Entry 1			275 275	2.14	0.09
SKYLINE-10 Left Entry 1	RERUN 1673.01	020928 1000	242	1.42	0.09

The ORIGINAL value was a little high as confirmed by two separate reruns. Please replace ORIGINAL with RERUN average of 1.39 TU.

Client: PETERSEN HYDROLOGIC-SKYLINE Purchase Order: Bill to: C. Hansen

Recvd: 03/01/17 Contact: E. Petersen, 801/766-4006

Job# : 1709 2695 N. 600 E.

Final: 03/03/24 LABORATORY RERUN SKYLINE MINE, 2002 Lehi, UT 84043

Cust LABEL INFO JOB.SX REFDATE QUANT ELYS TU eTU

PETERSEN-11 L TAIL BLEEDER 1 N 1709.07 021213 1000 275 0.69\* 0.09

\* RERUN agreed with ORIGINAL. Above value is average of duplicate runs

Client: PETERSEN HYDROLOGIC-UTAH POWER Purchase Order: 3000015409

Recvd: 03/01/17 Contact: E. Petersen, 801/766-4006

Job# : 1708 · 2695 N. 600 E.; Lehi, UT 84043

Final: 03/03/24 LABORATORY RERUN Results to Petersen - (UTAH POWER)

Cust LABEL INFO JOB.SX REFDATE QUANT ELYS TU eTU

PETERSEN-JC-1 OUT HUNT. CREEK 1708.03 030107 1000 275 1.83\* 0.09

\* RERUN agreed with ORIGINAL. Above value is average of duplicate runs.

301113230



Hydrologic Consultants, Inc. of Colorado 143 Union Blvd., Ste. 525 Lakewood, Colorado 80228 USA

telephone: 303-969-8033 fax: 303-969-8357

e-mail: hcico@hcico.com http://www.hcitasca.com

#### TECHNICAL MEMORANDUM

TO:

Mr. Chris Hansen

**HCI-1787** 

FROM:

Roger Howell - HCI

**SUBJECT:** 

Status of Ground-Water Flow Modeling for Skyline Mine

DATE:

May 23, 2002

#### 1.0 INTRODUCTION

Hydrologic Consultants Inc. of Colorado (HCI) is constructing a numerical model for Canyon Fuel Company (CFC) to represent ground-water flow in and around the Skyline Mine. The goal of this project is to develop a hydrogeologically-based model that will describe the hydrologic system in the vicinity of the Skyline Mine, and that can be used to identify potential effects of mining on the ground-water and surface-water resources of the region. The current objectives for the ground-water model are:

- To investigate the relationship between deep ground water and surface hydrology in the vicinity of the Skyline Mine.
- To evaluate various alternative sources and pathways of ground-water inflow to the Skyline Mine.
- To estimate the effect of mine inflow and pumping on surface-water resources.
- To predict future mine inflows and required pumping rate from dewatering wells.

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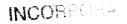
JUN 1 3 2003

### 1.1 History of Ground-water Modeling at Skyline

An early version of the Skyline ground-water flow model was completed in May 2002 (the May version) for the limited purpose of predicting dewatering requirements for mining in the Flat Canyon Tract. To save time and costs, the May version of the model did not include surface water hydrology, but modelled a no-flow top boundary to represent the thick, relatively-impermeable Blackhawk Formation above the mine. The assumption of low flow through the Blackhawk Formation was based on results of geochemical and geological studies at other sites in Utah (Mayo, and Morris, 2000) which indicate that the deep ground waters that provide inflows to the mine are much older than, and may not receive a significant amount of recharge from, the shallow ground-water system that draws recharge from precipitation. The results of the May version of the numerical model were presented at a meeting at Skyline Mine on 31 May 2002.

In August 2002 CFC requested that HCI upgrade the numerical ground-water flow model to include surface-water effects (specifically surface recharge to the ground-water system). Consequently, the May version of the model was updated with incorporation of upper stratigraphic units (Blackhawk Formation above the coal seams), more accurate fault locations, surface topography, and surface hydrologic features. Preliminary model runs conducted in October 2002 showed that the deep and shallow ground-water systems could be simulated together. However, the results were very sensitive to geological assumptions, primarily to assumptions regarding the thickness and elevation of the Starpoint Sandstones. At that time very little direct, concrete information about the deep portions of the Starpoint Formation was available.

In October it was decided by CFC and HCI to discontinue further development of the model until a geological compilation could be completed. A comprehensive study was subsequently undertaken by Skyline and their consultants to assess the physical extent of the Starpoint Sandstones, including a regional study of stratigraphy, and of structures (faults) that might limit or enhance the transmissivities of the sandstones. The study examined existing data from diverse sources, including drillhole logs from numerous gas-exploration wells drilled in the region; and



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Technical Memorandum May 23, 2003 Page 3

geological studies, including university theses, government investigations, and proprietary industry (mining and petroleum) reports.

## 2.0 CURRENT GROUND-WATER FLOW MODEL

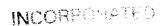
The geological compilation was largely completed by mid March 2003, and the results have since been incorporated into, and used to constrain, a current ground-water flow model. The current model has been successfully calibrated, and used in preliminary evaluations of ground-water flow and surface-water/ground-water interaction. The current model is described briefly below.

### 2.1 Area of Study

The hydrologic study area (HSA) of the current ground-water flow model is centered on the Skyline Mine in the northern Wasatch Plateau of central Utah. The area generally lies west of Pleasant Valley and the towns of Scofield and Clear Creek, and east of Gooseberry Valley and Skyline Drive. The HSA extends south to just beyond Electric Lake dam on Huntington Creek, and north to Fish Creek (Figure 1). The HSA is composed mostly of high, somewhat flat-topped mountains with deeply incised, heavily wooded valleys. The area is characterised by considerable relief with elevations ranging from 7,700 ft (NGVD) at the mouth of Fish Creek to over 9,800 ft at the headwaters of Gooseberry Creek. Ephemeral streams on the west and east flanks of the HSA flow northward and discharge through Scofield Reservoir, while streams in the center of the HSA flow southward and discharge through Electric Lake Reservoir.

## 2.2 Description of Numerical Model

The term "model" or "numerical model" refers to a specific combination of a code, a finiteelement mesh, hydrologic data, and boundary conditions that describe a specific set of site conditions. The term "code" or "numerical code" is used to refer to a computer program that solves a system of equations that describe a ground-water flow problem. The term "numerical



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model" should not be confused with the "conceptual hydrogeologic model" which is a qualitative description of the physical ground-water flow system simulated by the numerical model.

## 2.2.1 Numerical Code used in Current Model

The numerical modelling described in this letter report utilises the numerical code MINEDW which solves three-dimensional ground-water flow problems with an unconfined, or phreatic, surface using the finite element method. This code was developed and copyrighted by HCI (Timothy J. Durbin, P.E., is the primary author) to solve problems related to mine dewatering. MINEDW has several special attributes that specifically address conditions common to mine dewatering (Atkinson and others, 1992). MINEDW also utilises a variable flux boundary condition as an alternative to generating unnecessarily large model grids.

## 2.2.2 Model Mesh and Discretization

The current model grid is shown in Figure 2. Other physical properties of the model are listed in the table below.

Discretization of Model			
Number of Layers	13		
Number of Nodes	29,316		
Number of Elements	53,040		
Number of Hydrogeologic Units	32		
Model Area (mi²)	88		

## 2.3 Inputs to the model

The basic data that have been compiled for use in the ground-water flow model are listed below.

- 1) Geology, including a comprehensive compilation of the structure and stratigraphy of the Starpoint Sandstones.
- 2) Water level data from 21 piezometers, including pre-mining records from archived records, and current recordings of water-level changes.
- 3) Mining history, including a panel-by-panel chronology of the excavation of the Skyline Mine.
- 4) Total mine inflow, and timing and discharge rates of individual mine inflows
- 5) Pumping schedules and rates from the James Canyon Wells.
- 6) Stream baseflows and precipitation records.
- 7) Measured and estimated hydraulic parameters of the principal formations.
- 8) Boundary Conditions.
- 9) Constraints of geochemistry and reservoir operations

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### 2.3.2 Hydrogeologic Units

Eight major hydrogeologic units have been identified in the HSA. The units are shown graphically in Figure 3. In general, from shallowest to deepest, they include overburden, upper coal (LOA) and lower coal (LOB), Storrs and Panther Sandstones, and Starpoint Sandstone, with interburden units between all.

Overburden comprises the top 3 layers of the model. Multiple layers of overburden are necessary both to model a surface zone more open and porous than rocks below, and to model the propagation of fractures upward through the lower overburden as mining progresses. Initial hydraulic conductivities (pre-mining) are relatively low compared to all other hydrostratigraphic units in the model, and horizontal/vertical anisotropies are high (100:1).

Both coal units (LOA and LOB) initially are assigned relatively high horizontal hydraulic conductivity (similar to a sandstone) with anisotropies of only 1:1, representing heavily-cleated coal. The upper coal is differentiated in order to account for early mining and mine inflows.

The Starpoint Formation is modelled with two layers for numerical reasons. Both layers include, conceptually, multiple sandstone units and shales interbedded with the sandstones. Consequently, the Starpoint layers are assigned properties that account for the anisotropy imparted by the interlayering.

Interburden layers occur between the coal and sandstone layers. The interburden layers initially are assigned properties similar to the lower (pre-mining) overburden.

The Mancos Shale, beneath the Starpoint Formation, is implicitly modelled as a no-flow boundary at the base of the model.

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#### 2.3.3 Surface-Water Flows

Streams in the HSA were simulated using drain nodes along the courses of the streams. The drain nodes were assigned heads taken from U.S.G.S-based topographic data. Fluxes through the drain nodes were then summed to yield a value for streamflow, from which recharge rates could be checked.

Electric Lake was simulated with constant head nodes. A head of 8,545 ft represents the mean reservoir stage over the last 28 years.

#### 2.3.4 **Pumping and Mine Inflows**

Pumping from JC-1 and JC-2 is simulated explicitly in the model as a pumping well node located on the Diagonal Fault. Mine inflows are implicitly simulated using drain nodes, with leakance matched to estimated inflow rates through time. The inflow nodes are also located along the appropriate faults.

#### **2.3.5 Mining**

Ground-water inflow induced by mining is simulated by assigning drain nodes to the area being mined. We have incorporated lower node leakance values (0.0001) for room and pillar areas than for longwall mining areas (1.0) to be able to simulate the lower inflows that are known to have occurred in the room and pillar areas.

In the numerical simulations, the hydraulic conductivity of the approximately 100-ft thick zone above a panel that is mined is increased by a factor of 10 (as described in Section 3.0). The longwall operation is simulated on a yearly basis based on existing and proposed mine plans provided to HCI by Skyline.



#### 2.4 Model Boundaries

As in earlier versions of the model, the boundaries for the Skyline model have been selected to coincide with natural hydrologic boundaries, where possible, to limit the amount of ground-water and surface water flow that naturally enter and exit the HSA. The east and west boundaries of the model, as before, are defined by the Pleasant Valley and Gooseberry Faults, respectively. Both regional faults juxtapose the Starpoint Sandstones against thick sequences of low-permeability sediments. The north model boundary coincides with the south fault of the Fish Creek graben, in Fish Creek Canyon. The final boundary, at the south end of the HSA south of Electric Lake, is also defined (though only approximately) by surface-water divides. With the exception of the southern boundary, all boundaries are treated as no-flow boundaries in both steady-state and transient simulations.

The southern boundary of the current model is not as well constrained as the other boundaries. The southern boundary west of the Connelville Fault, for steady-state calibration, is defined with constant-head nodes in order to match the sloping piezometric surface seen in well data. The nodes are then assigned a constant flux (measured during steady state) for transient simulations. East of the Connelville Fault the southern boundary is set as no-flow partly as a default condition. Specified flux will not work to the east as it does to the west because of the exposures of Starpoint Sandstone in Huntington Canyon. The no-flow boundary in this reach forces ground water to discharge from the sandstones into Huntington Creek, as seen in the numerous springs along the canyon walls.

## 3.0 RECOMMENDED EXPANSION OF CURRENT MODEL

The ground-water flow model described above calibrates very well to pre-mining water levels measured and projected in regional piezometers. The transient calibration closely matches local drawdown of water levels, and mine-inflow rates. It is HCI's opinion that the current model provides an accurate characterization of ground-water flow in the vicinity of Skyline Mine.

However, preliminary simulations have shown the ground-water flow around the south end of Electric Lake to be very sensitive to the southern boundary conditions. Because of the intense interest that has developed recently in the interactions between surface water and ground water near Electric Lake, this model may be used more to simulate those interactions than for any other use. Consequently, HCI recommends that the uncertainties due to the current southern boundary be removed.

The assignment of the current southern boundary conditions follows standard modeling techniques. However, the boundary location, reasonable when the model was to be used for mine-dewatering scenarios, may now be inappropriate for scenarios involving surface-water bodies – especially Electric Lake. To provide a more robust and less potentially controversial model solution, the boundary should be moved to a more definitive topographic or hydrogeologic divide. HCI suggests expanding the model domain southward, and setting the eastern portion of the southern boundary in Left Fork of Huntington Creek. There the nodes can be assigned constant head values equal to the elevation of the bottom of the Starpoint Sandstones in that canyon. The western portion of the southern boundary might be moved as far south as the divide between Scad Valley and Joes Valley, and the nodes assigned a no-flow condition coinciding with the surface-water divide.

Expanding the model domain will require collection of additional geologic and hydrologic data to cover the new area. A preliminary search has shown very little available geologic data in this area. Consequently, some time will be needed to conduct field mapping of the major strata and structures. During that period a search will also be made for any records of deep drilling in the area of interest, as well as for any water-level and useable stream flow data. HCI estimates that

the additional field work and data search will take until mid August, 2003, at which time modeling can resume. A final report of model findings, therefore, will be prepared by September 30, 2003.

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Mayo, A.L., and Morris, T.H., 2000, Conceptual model of groundwater flow in stratified mountainous terrain, Utah, USA *in* Groundwater – Past achievements and future challenges, Sililo, O., et al., eds., Proceedings of XXX IAH Congress on Groundwater, Cape Town, South Africa, 26 November - 1 December 2000, A.A. Balkema, Rotterdam, pp. 225-229.



# PETERSEN HYDROLOGIC

5 June 2003

Mr. Chris Hansen Environmental Coordinator Canyon Fuel Company, LLC Skyline Mine HC 35 Box 380 Helper, Utah 84526

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Chris,

At your request I have prepared this summary of the ongoing dye tracing study at Electric Lake. The dye placement activities, dye monitoring locations, sample collection procedures, and study results to date are summarized in this letter report. It should be noted that this information is preliminary in nature. Details regarding PacifiCorp's dye placement activities are based largely on communications from PacifiCorp personnel. PacifiCorp is also placing and retrieving dye collection packets, but we are unaware of their procedures and results.

In mid-February 2003, PacifiCorp personnel injected an unknown quantity of fluorescent dye into the substrate of Electric Lake near three inferred fault locations. It was thought by PacifiCorp that significant quantities of water were leaking from Electric Lake through these faults. The specific type of dye used is not known, although it was apparently a type of fluorescein dye.

Subsequent to the initial dye emplacement, a second dye injection took place on 1 April 2003. It is reported that on this date approximately 35 pounds of fluorescein dye was injected into the southernmost north-south trending fault, and approximately 50 pounds of eosine dye was injected into a northerly east-west trending fault in the lake bottom. At both locations, the powdered dye was mixed onsite with lake water in plastic containers. The liquid dye mixture was then pumped though a PVC pipe into the sediments at the bottom of the lake.

A dye-monitoring program was initiated by Petersen Hydrologic on 5 March 2003 to monitor for the presence of dye in surrounding groundwater and surface-water bodies. Dye monitoring stations included locations within the Skyline Mine, JC-1 discharge, locations in Huntington Creek and its tributaries below Electric Lake, springs and wells in the Huntington Creek and Mud Creek drainages, and locations in Mud Creek and its tributaries. Dye monitoring locations are shown on Plate 1.

Mr. Chris Hansen Page 2 of 3

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Monitoring for fluorescent dye was performed by placing laboratory-supplied packets containing activated charcoal into a water source for a period of time. The activated charcoal packets were wired to heavy objects and placed in actively-flowing portions of the spring or stream substrate. At each monitoring event the charcoal samplers were collected and new packets were placed. New latex gloves were worn during each monitoring event to prevent sample contamination. The collected sample packets were double bagged and kept under refrigeration until delivery to the laboratory. Samples were shipped to the laboratory under refrigeration via overnight service in new, sealed shipping coolers.

Fluorescent dye accumulates on the activated charcoal if a pulse of dye passes by the sampling device. Using the charcoal packet sampling method, continuous monitoring for dye is achieved, and dye detections at the parts-per-trillion level are possible. Laboratory detection of dye on the activated charcoal samplers was performed by Ozark Underground Laboratory, Inc. of Protem, Missouri. It is our understanding that this same laboratory is being used by PacifiCorp for their laboratory dye analyses.

Dye monitoring results are listed in Table 1. It should be noted that the laboratory reported dye concentrations listed in Table 1 are concentrations of dye in the eluant solution associated with the extraction of the dye from the charcoal samplers. The reported values are not representative of instantaneous dye concentrations in the water source.

It is noteworthy that no dye has been detected in JC-1 discharge in the  $2\frac{1}{2}$  months since the dye was placed in the lake. As anticipated, dye has been detected in the outflow of Electric Lake and at downstream locations. Low concentrations of both fluorescein and eosine dye have also been detected in other locations in the study area (Table 1)<sup>1</sup>.

<sup>&</sup>lt;sup>1</sup> In addition to the dye monitoring program described above, an investigation was performed to determine the extent to which the use of antifreeze could be responsible for the trace concentrations of fluorescein dye detected in the vicinity of the Skyline Mine (Table 1). Antifreeze is widely used in mine vehicles and equipment, both underground and at the surface. Employee and vehicles parked at the mine parking area and vehicles traveling on State Highway 264 adjacent to Eccles Creek also utilize antifreeze.

A sample of antifreeze of the type used in mine equipment was obtained from the mine shop for analysis. The antifreeze was diluted with dye-free distilled water to a concentration of approximately 1.2%. A charcoal sampler was placed in this solution for a period of 2.75 hours. Laboratory analysis of this charcoal sampler indicated a positive detection for fluorescein dye at 505 ppb. To determine whether fluorescence is present in runoff from the mine facilities, charcoal samplers were placed in two surface-water drainage collection systems at the mine. Laboratory analysis indicates that both of these charcoal samplers tested positive for fluorescein (9.76 ppb and 2.24 ppb; Table 1).

The results of this antifreeze investigation suggest that fugitive antifreeze may be responsible for trace fluorescein detections, particularly those in areas where water could have been influenced by water coming from highways or areas where mine equipment was operated.

Mr. Chris Hansen Page 3 of 3

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Please feel free to contact me if you have any questions in this regard.

Sincerely,

Erik C. Petersen, P.G. Principal Hydrogeologist

# FINDINGS OF GROUND-WATER FLOW MODELING OF SKYLINE MINE AND SURROUNDING AREA, CARBON, SANPETE, AND EMERY COUNTIES, UTAH

## Prepared by

Hydrologic Consultants, Inc. of Colorado an HCItasca Company

for

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HCI-1787

September 2003



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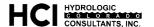
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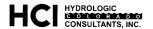
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# EXECUTIVE SUMMARY (Page 1 of 2)

- 1) This report describes the findings of a three-dimensional ground-water flow model that was developed to evaluate the relationship between ground water and surface water in the vicinity of the Skyline Mine. A preliminary version of the model had been constructed solely to predict dewatering requirements for proposed mining in the Flat Canyon tract. This updated and more comprehensive version of the model incorporates data on surface-water hydrology, considerably more ground-water level data, and more detailed information on stratigraphy and structures from a recently completed, sub-regional geologic mapping program.
- 2) Large, persistent ground-water inflows have been encountered in the Skyline Mine since March 1999. The total inflow rate to the mine from 8 major inflows reached a maximum of more than 10,000 gpm in April 2002, but has since declined to less than 8,000 gpm.
- 3) PacifiCorp, the operator of Electric Lake, which is located above and west of the mine workings, have questioned whether water flowing into the Skyline Mine is coming from the reservoir. Together with water chemistry, temperature, and inflow-decay data, results of this model suggest that the vast majority of water flowing into Skyline Mine workings comes from the deep ground-water system.
- 4) The hydrostratigraphy of the study area is dominated by approximately 1,500 ft of Starpoint Formation sandstones and siltstones overlain by an equivalent thickness of shales and siltstones of the Blackhawk Formation. The Skyline Mine extracts coals at the boundary between these two major units.
- 5) Faults with large vertical displacement (the Pleasant Valley, Gooseberry, Fish Creek Graben, and Valentine Faults, and portions of the O'Connor Fault) impede horizontal ground-water flow, whereas numerous north/south-trending structures of small displacement, including portions of the Connelville Fault, locally transmit water.
- 6) Ground-water levels in monitoring wells indicate that there are two continuous, but poorly connected ground-water systems in the vicinity of the Skyline Mine. The relatively shallow ground-water system in the Blackhawk Formation is characterized by water levels between 150 and 350 ft below ground surface. A deep aquifer system comprised of the Starpoint Sandstones and coals at the boundary between the Starpoint and Blackhawk Formations exhibits water levels 500 to 1,000 ft below ground surface. Inflows to the mine and ground-water pumping since 1999 have resulted in drawdown of as much as 400 ft over a broad area in the deep aquifer, but they have not affected ground-water levels in the shallow ground-water system.



# EXECUTIVE SUMMARY (Page 2 of 2)

- 7) Pre-mining water-level data indicate that the potentiometric surface of the deep aquifer in the area of the mine had a regional gradient from south-southwest to north-northeast in the range of 0.03 to 0.009 ft/ft. Most of the recharge to the deep aquifer probably occurs in the high country to the south of Huntington and Cleveland Reservoirs. Ground-water discharge is believed to occur in the vicinity of Scofield Reservoir, although direct evidence of the discharge has not been observed.
- 8) The calibrated ground-water flow model replicates the mine inflows and water levels in monitoring wells quite reasonably. However, the calibration to gaged and estimated stream baseflows is not as good. The calibration to stream baseflows is weakest at the north end of the model where the model-simulated ground-water discharge to streams includes large discrete discharges from the deep aquifer. In reality, the deep discharge is thought to be more diffuse due to a structural setting more complicated than can be represented by this (or any) model.
- 9) Simulations of the local ground-water/surface-water system with the numerical model indicate that all of the water that has flowed into the Skyline Mine can be accounted for by depletion of storage in the deep Starpoint aquifer system. No shallow ground-water or surface-water source is necessary to account for the inflows. In fact, efforts to "force" surface water from Electric Lake into the mine with the model require unreasonably high values of hydraulic conductivity for the faults beneath the lake.
- 10) The pre-mining ground-water flow through the deep aquifer system in the area roughly between the O'Connor and Gooseberry Faults is estimated to have been about 5 cfs (2,200 gpm). The model estimates that current mine inflows and pumping have had only a very small effect (about 0.5 cfs or 250 gpm) on the rate of discharge in the area of Scofield Reservoir. The numerical simulations predict that by 2013, this impact will increase to about 2.2 cfs (1,000 gpm).
- 11) The model also predicts that the inflow rate to the Skyline mine from all sources will decrease by 2013 to approximately 3,700 gpm as a result of diminished hydraulic heads in the deep aquifer system.





#### 1.0 INTRODUCTION

Skyline Mine, operated by Canyon Fuel Company (CFC), is a longwall coal mine located in the northern Wasatch Plateau of central Utah. The mine began operations in the early 1980s; and throughout the development of Levels 1 and 3 (see Figure 1), it encountered ground-water inflows typical of underground coal mines in the western U.S. The inflows were small (less than 300 gpm), usually issued from the roof, and typically would dissipate over one to several months.

Beginning in 1999, mining on Level 2 encountered a number of large, persistent ground-water inflows related to a set of north- to northeast-trending normal faults of relatively small displacement. Initial discharges at individual locations might have been as large as 6,500 gpm, although discharges of about 1,000 gpm were more typical. The discharges at individual fault intersections have decreased slowly, with as much as 30 to 50 percent of the original maximum inflow rate continuing after a period of four years. The total mine inflow reached a peak of about 10,500 gpm in March 2002, and has since decreased to about 7,500 gpm as of March 2003. Figure 1 shows the locations of the major inflows within the Level 2 mine workings.

Mitigation efforts have had only a minor effect on decreasing the inflow rates in the mine. Mining has since been completed in most of Level 2, and ground water has been allowed to flood portions of the 8-Left and 9-Left longwall panels up to seals placed in the entries at the head of 8-Left panel. In consideration of potentially large additional dewatering costs, CFC has put on indefinite hold their plans to develop the proposed Flat Canyon tract (Figure 1).

At the same time that ground-water inflows were disrupting operations in the Skyline Mine, PacifiCorp, the operator of Electric Lake reservoir, reported that water levels in the lake were declining at what they perceived to be an anomalously rapid rate. The high-water line of Electric Lake lies about 600 ft above, and about 2,400 ft west of the 10-Left entries. PacifiCorp concluded that water from Electric Lake was entering the Skyline Mine.

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Results of water chemistry analyses continue to indicate that ground waters entering the mine and being pumped from the James Canyon wells are from a very old, deep source, and contain, at most, a small fraction of shallow ground water. Furthermore, dye-injection tests carried out by PacifiCorp also have shown no connection between the lake and the mine inflows and pumping wells (PacifiCorp, 2003).

#### 1.1 PREVIOUS WORK

Hydrologic Consultants, Inc. of Colorado (HCI) submitted an initial progress report (HCI, 2001) to CFC in December 2001 describing the findings of a preliminary hydrogeologic investigation and the results of efforts to mitigate the large inflow at 10-Left. The report included the preliminary results of water chemistry analyses indicating that ground waters entering the mine and being pumped from the James Canyon wells are isotopically distinct from surface waters. HCI (2001) also included a description of the results of pumping from the James Canyon wells, a compilation of water-level data from monitoring wells, and a preliminary analysis of changes in monitoring-well water levels attributable to the mine inflows. A second progress report (HCI, 2002a) included a more encompassing investigation of geologic structures and stratigraphy beneath the mine site and concluded that the shallow and deep ground-water flow systems in the mine area responded separately to hydraulic stresses. HCI (2002a) also included additional analysis of the effects of pumping from the James Canyon wells on mine inflows.

A third progress report (HCI, 2003) summarized HCI's further analysis of hydrogeologic data collected since the largest of the mine inflows began and presented a preliminary assessment of the interaction between the surface water and the deep ground-water flow system. HCI's interpretation of the apparent structural compartmentalization within the deep aquifer, the premining and early-mining ground-water conditions in the area, and the locations of recharge to and discharge from the deep aquifer were also described. In addition, HCI (2003) summarized

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the surface-water hydrology in the area above the mine, and evaluated the hydraulic parameters of key hydrostratigraphic units.

An early version of a ground-water flow model was completed in May 2002 for the limited purpose of predicting dewatering requirements for mining in the Flat Canyon Tract. For that purpose and to save time and costs, the early model version did not include surface-water hydrology and included a no-flow top boundary to represent the thick, relatively-impermeable Blackhawk Formation above the mine. The assumption of no-flow through the Blackhawk Formation was based on findings of geochemical and geological studies at other sites in Utah (Mayo, and Morris, 2000) which indicate that the deep ground waters that provide inflows to the mine are much older than and do not receive a significant amount of recharge from the shallow ground-water system that, in turn, receives recharge from precipitation.

The results of the early model were presented at a meeting at Skyline Mine on 31 May 2002. The model did not predict the dewatering requirements for a "dry" mine, but rather the amount of active dewatering that would have to be implemented to keep residual passive inflows to a manageable rate. In August 2002, CFC requested HCI to update the ground-water flow model with additional water-level data, and to incorporate surface-water effects (specifically surface recharge to the ground-water system) in order to achieve the objectives stated above. HCI identified four specific tasks that had to be completed in order to revise the model:

- 1) Incorporation of more accurate stratigraphy and fault locations to simulate the outcrops of sandstones in areas of potential recharge/discharge.
- 2) Incorporation of surface topography. The strata would be "hung" as before on the LOB coal layer; but with the new model, the topmost overburden units would be extended to the ground surface.
- 3) Definition of streams on the top surface of the model as drain nodes at elevations defined by the topography.
- 4) Calculation of recharge to the ground-water system from orographically controlled precipitation.

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Incorporation of detailed stratigraphy and geologic structures proved to be the most time-consuming aspect of the model update, and modeling work had to be put on hold awaiting completion of a separate study by Kravits (2003). The modeling re-started in March 2003, and the initial results demonstrated extreme sensitivity to the boundary conditions to the south of the model domain. Consequently, the modeling was again put on hold from June until September 2003 until the stratigraphy and structures in the area south of Electric Lake could be better defined and incorporated into the model.

#### 1.2 CURRENT INVESTIGATION

The goal of the current investigation is to develop a hydrogeologically-based numerical ground-water flow model that can:

- 1) describe the ground-water system in the vicinity of the Skyline Mine,
- 2) be used as a management tool for both the ground-water and surface-water resources of the region, and
- 3) evaluate significantly different explanations of the source of ground water flowing into the mine.

As the typical first step in building a numerical ground-water flow model, a conceptual hydrogeologic model is developed that is based on regional and local geology, data from drillholes and hydraulic testing, and long-term monitoring of water levels, stream flows, etc. However, as will be evident below, many of the components necessary for the Skyline model are not well defined. Water-level data are sparse in both the shallow ground-water system and the deep Starpoint aquifer (described below). Other conceptual components with considerable uncertainty (since no pumping tests have yet been done in the Blackhawk or Starpoint Formations) are the values for hydraulic conductivity for each of these major hydrogeologic units, and relative permeabilities of the major structures.



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Consequently, the conceptual hydrogeologic model of the Skyline Mine area is still being developed. Although some components such as recharge or stratigraphic thicknesses can be reasonably well defined by the available data, other major components such as the vertical hydraulic conductivity of overburden units or the hydraulic characteristics of faults can only be evaluated from the reasonableness of the results of preliminary numerical simulations using assumed values. As such, the Skyline model is still in a heuristic stage in which it is being used to learn about the characteristics of the regional ground-water flow system. Nonetheless, it is also being used at the same time to predict hydrologic outcomes under alternative assumptions.

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## 2.0 HYDROLOGIC SETTING

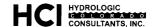
The hydrologic study area (HSA) is centered on the Skyline Mine in the northern Wasatch Plateau of central Utah. It generally lies west of Pleasant Valley and the towns of Scofield and Clear Creek and east of Gooseberry Valley and Skyline Drive. The HSA extends south to the Paradise Creek Valley divide in Joe's Valley and north to the confluence of Gooseberry and Fish Creeks (Plate I).

The HSA is comprised mostly of high, somewhat flat-topped mountains with deeply incised, heavily wooded valleys. It is characterized by considerable relief with elevations ranging from 7,700 ft (NGVD) at the mouth of Fish Creek to more than 10,000 ft at the headwaters of Left Fork of Huntington Creek (Plate I). Ephemeral streams on the west and east flanks of the HSA flow northward and discharge through Scofield Reservoir, while streams in the center of the HSA flow southward and discharge through Electric Lake Reservoir.

#### 2.1 STRATIGRAPHY

The HSA straddles the western margin of the Cretaceous Western Interior epi-continental seaway. Subsidence along the western edge of the basin during most of Cretaceous time coincided with orogeny along the Sevier Belt to the west, and resulted in a thick accumulation of terrigenous clastic sediments shed eastward into deeper-water environments. The stratigraphic units of greatest interest in this study, the Mancos Shale, Starpoint Sandstone, and Blackhawk Formation, are all of upper Cretaceous age. The Mancos shale demarks the bottom of the model, as described below, and is of marine origin. Deposition of the Starpoint Sandstone above the Mancos Shale represents a general regression of the sea, and shallow-water deposition for an extended period along a stable shoreline. Deposition of the Blackhawk Formation culminated the regression of the sea as pro-grading delta and coastal swamp sediments, including overbank muds, channel sands, and coals, rode over the beach deposits.

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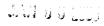


CFC has mapped and compiled the geology in the region around the Skyline Mine, and their interpretation of the geologic relationships and principal structures (CFC, 2002) is shown on Plate II. The Skyline Mine is developed in the O'Connor and Flat Canyon coals, members of the Blackhawk and Starpoint Formations, respectively. The overburden consists primarily of siltstones, sandstones, coals, and shales of the Blackhawk Formation. Sandstones, subordinate to the shales and siltstones, generally occur in elongate bodies, and represent distributary channel deposits. The Blackhawk Formation is overlain by later Cretaceous and early Tertiary continental sedimentary rocks in the high country west and south of Electric Lake (Units of the North Horn and Price River Formations). The upper sedimentary units are not distinguished from Blackhawk Formation overburden in the model.

Units underlying the principal coals include interbedded siltstones and sandstones interpreted to be a stacked transgressive-regressive shoreline assemblage. The two proximal sandstone units beneath the coal seams, and hence the two most well known, are the Storrs and Panther Sandstones (Figure 2). The Storrs and Panther sandstones are each about 40 to 60 ft thick, and are separated by approximately 30 ft of shale and coal.

Numerous additional shoreface sandstone units locally underlie the Panther Sandstone. The log of one nearby drillhole (reproduced in Figure 2) shows a stacked sequence of sandstones totaling at least 800 ft in aggregate thickness within a total stratigraphic thickness of 1,100 ft. CFC has interpreted the sandstones represented in the log to be of shoreface affinity (M. Bunnell, 2002, personal commun.). Regional studies have shown that the individual sandstone bodies within the Starpoint Formation are elongate in a north-south direction, parallel to the ancient shoreline, and interfinger seaward (to the east) with the Mancos Shale and landward with Blackhawk sediments (Flores et al., 1984).

Kravits (2003) compiled the logs of 17 deep gas exploration boreholes and about 30 coal exploration boreholes in the northern Wasatch Plateau. He found that the Starpoint Sandstones, as described above, extend beneath and beyond the boundaries of the model domain. The total





thickness of the Starpoint Formation increases and decreases locally, within a range of 200 to 1,500 ft. The formation is thickest along a north-northeast axis running through the approximate center of the HSA and thins both eastward and westward. The proportion of sandstone vs. shale in the Starpoint Formation varies from about 70:30 to about 90:10, with the highest proportion occurring where the formation is thickest. The stratigraphic data from Kravits (2003) including elevations of various units, thicknesses, and sandstone/shale ratios have been incorporated into the model.

#### 2.2 STRUCTURE

Strata in the HSA generally dip at a shallow angle to the west and are locally folded in subdued, open folds. The strata in the vicinity of the Skyline Mine dip in three directions away from the portal at a fairly constant angle of about 4 degrees. Numerous faults cut the sedimentary rocks in the vicinity of Skyline Mine. The major faults include the generally north-south trending Pleasant Valley Fault Zone along Mud Creek to the east of the HSA and the Gooseberry Fault Zone in Gooseberry Creek to the west (Plate II). The vertical components of displacement across these two major faults have been estimated to be several hundred feet to more than 1,000 ft, respectively. Roughly east-west striking faults comprise the Fish Creek graben at the north end of the HSA. Vertical displacements on both of the faults bounding the Fish Creek graben are estimated to be 800 to 1,200 ft (Kravits, 2003).

Three intermediate- to large-magnitude faults in the interior of the HSA (between the Pleasant Valley and Gooseberry Faults) include the Connelville, O'Connor, and Valentine Faults, all to the east of the mine workings (Plate II). The three faults strike north-south to northeast-southwest; and according to Kravits (2003), all of them appear to have differential displacement along their strikes (i.e., they are "hinge" faults). The Connelville Fault defines the southeast boundary of the Skyline Mine and the northwest boundary of the White Oak Mine (Figure 1). The Connelville Fault exhibits about 250 ft of vertical displacement along its trace





from Scofield south to Electric Lake. South of Electric Lake, the displacement increases rapidly to as much as 1,300 ft in Joe's Valley.

The relative displacement on both the O'Connor and Connelville Faults is down to the west. However, the "hinge" direction is opposite in the two faults. The O'Connor Fault exhibits at least 600 ft of displacement along its trace from Pleasant Valley south to Electric Lake, but only about 100 ft of displacement south of Electric Lake. The O'Connor and Connelville Faults appear to join near Miller Flat Reservoir in Joe's Valley. The Valentine Fault occurs just east of the O'Connor Fault, and it also has downward displacement to the west. Along the trace of the Valentine Fault on the west slopes of Pleasant Valley, the displacement might be as little as 200 ft. To the south, however, the displacement increases to as much as 1,400 ft where the Valentine forms the western boundary of the Joe's Valley graben.

A number of lesser faults and fracture zones also occur between the Pleasant Valley and Gooseberry Creek Faults, many of which have been encountered in the workings of Skyline Mine (Plate III). In the Level 2 mine, the 11-Left, 14-Left, and 16-Left Faults trend northeast-southwest, at an angle to the Pleasant Valley and Gooseberry Creek Faults, but parallel to the Connelville Fault (Plate II). The Diagonal Fault trends north-south, parallel to the regional faults, and apparently intersects both the Connelville and 14-Left Faults. The Diagonal Fault is the largest of the faults that have been encountered in the mine and exhibits as much as 60 ft of vertical displacement. The 14-Left and 16-Left Faults locally show only about 10 ft of vertical displacement.

In the Level 3 and Winter Quarters mine areas, no significant north- or northeast-trending faults have been mapped. CFC's structural interpretation shows mostly east-west trending faults of minor displacement north of the Level 2 workings. The West Mains Fault is the most prominent east-west fault and has about 30 ft of vertical displacement. East-west trending igneous dikes locally accompany the east-west faults (Plate III). CFC's geologic maps suggest that the north- and northeast-trending faults cut the dikes.



#### 2.3 PRECIPITATION AND EVAPOTRANSPIRATION

A weather station maintained below Electric Lake Dam is at an elevation of 8,400 ft, and two nearby stations, Mammoth-Cottonwood and Red Pine Ridge, lie at elevations of 8,800 and 9,200 ft, respectively. Average annual precipitation at these weather stations over a 23-year period (1978 to 2001) ranges from about 24 inches at Electric Lake up to 32.4 inches at Red Pine Ridge. Regression analysis of a plot of average precipitation at the three weather stations vs. elevation defines a relationship from which average precipitation can be estimated for different elevations within the HSA:

$$P = 0.0105 \cdot z - 63.9 \tag{1}$$

where:

P = average annual precipitation (inches), and z = average elevation of land surface (ft, NGVD).

The correlation coefficient,  $R^2$ , for this relationship is 0.988. Estimates of average annual precipitation range from 41 in/year at an elevation of 10,000 ft to 18 in/year at 7,800 ft near the town of Scofield. Precipitation is highest in November through March, and lowest in June-July.

HCI estimated the evapotranspiration (*Et*) rate for the forests within the HSA to be approximately 65 percent and for the grass/sage to be 35 percent (HCI, 2002b). Within the forests, aspen comprises about half of the forest cover, and spruce/fir comprise the remaining half. Using these vegetation coverage estimates, the average potential evapotranspiration rate across the HSA is about 15.2 inches per year.

#### 2.4 SURFACE WATER

The HSA is drained by three major streams:

1) Fish Creek (including Gooseberry Creek) that drains the west side of the domain, flowing northward and then eastward into Scofield Reservoir.



- 2) Mud Creek that drains the eastern side of the domain, also flowing northward into Scofield Reservoir.
- 3) Huntington Creek, including the Left Fork, that drains the center of the domain. Its main fork flows southward through Electric Lake Reservoir, while the Left Fork flows westward and southward to join the main fork below the dam.

The streamflows peak in May-June with spring runoff, and the lowest flows occur in December and January. October mean flows, generally considered to represent baseflow in the western interior U.S., span wide ranges for all three major streams as a consequence of relatively wet autumns in the HSA. Nevertheless, baseflows computed from October average flows are shown in Table 1.

The HSA includes five reservoirs, Electric Lake, Huntington, Cleveland, Miller Flats, and Rolfson Reservoirs. At high water, Electric Lake covers about 430 acres. The remaining four reservoirs range in surface area (at high water) from about 40 to about 140 acres. Scofield Reservoir lies just outside the northeast boundary of the HSA.

#### 2.5 GROUND WATER

#### 2.5.1 Monitoring Network

Current shallow ground-water level data are available from four monitoring wells (W79-26-1, 79-10-1b, 79-14-2a, and 79-35-1b). In addition, records from shallow monitoring well 79-22-2-1 are available from 1982 through at least 1991. Plate I shows the locations, and Table 2 lists coordinates, elevations, and screened intervals of all known ground-water monitoring wells.

Deep ground-water level data are available from 13 currently serviceable monitoring wells (Plate I). At least half of these wells, however, were constructed after significant

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ground-water inflows had been encountered by mining. In addition, some historic water level records are available from monitoring wells that have since failed. Electronic monitoring devices have been used to record water levels in six monitoring wells (Table 2).

#### 2.5.2 Current Ground-Water Levels

The shallow monitoring wells in the HSA measure water levels both in the shallow ground-water system within the Blackhawk Formation including some discontinuous and locally perched zones of ground water. Water levels in monitoring wells such as 79-10-1b, 79-22-1, and 79-35-1b (Table 2) represent the continuous shallow ground-water system. In these wells, the water levels occur at 150 to 350 ft below ground surface (bgs) and generally do not respond to seasonal conditions. The shallow water levels correlate from drillhole (although the data are sparse) and generally define a water table that approximately mimics topography. In the HSA, the current water table shows relief of nearly 500 ft, with the highest water level elevation (9,032 ft) measured in well 79-10-1b on the high ridge between Huntington and Winter Quarters Canyons and the lowest water level elevation (8,565 ft) measured in 79-35-1b in the bottom of Burnout Canyon.

Underground mining in the HSA appears to have had local, measurable effects on water levels in the shallow ground-water system. Large, relatively short-term oscillations are apparent in the hydrographs of some shallow wells (Figure 3), and are most likely the result of subsidence-induced changes in porosity (or storage) as mining passes under the area and the subsequent recovery due to recharge. The hydrographs of the shallow wells in Figure 3 do not show the continuous decline in water levels in response to the large inflows in the Level 2 mine that the hydrographs of the deeper monitoring wells clearly exhibit.

The deep ground-water system beneath the HSA has been variously described as the "regional aquifer," the "Blackhawk/Starpoint aquifer," or just the "Starpoint aquifer." In this study, it will be simply referred to as the "deep aquifer." It should be clearly understood

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that the shallow ground-water system (excluding locally perched groundwater) and deep aquifer are components of a continuous ground-water system and are not hydraulically disconnected. However, because of the significant amount of low hydraulic conductivity material between them, the two systems respond to hydraulic stresses quite differently.

The deep aquifer is represented by water levels measured in wells that are screened in the Upper O'Connor (UC), Lower O'Connor B (LOB), Lower O'Connor A (LOA), and Flat Canyon coals and in the laterally continuous sandstone units between and beneath these coals (i.e., the Storrs, Panther, and Starpoint Sandstones). Ground-water levels in the deep system are generally 50 to 500 ft lower than in the overlying shallow Blackhawk aquifer, depending on topography and on the relative depths of the well screens. As can be seen in Figure 3, water levels in the deep monitoring wells have drawn down significantly beginning in 1999 (at about the time that large inflows were first encountered in the Level 2 Mine). Figure 4 shows the potentiometric surface in the deep system near the Skyline mine as of April 2003.

#### 2.5.3 **Pre-Mining Ground-Water Levels**

HCI (2003) included a compilation of pre-mining water levels measured in 11 of the deep monitoring wells within the HSA. Earlier investigations that reported or discussed some pre-mining water-level measurements included Vaughn Hansen Associates (1979, 1981, and 1982), Coastal (1992), and Norwest (2000). In general, "pre-mining" refers to conditions prior to opening of the Skyline Mine in the early 1980's. However, hydrologic data from the 1970's and early 1980's are sparse, so that in some instances pre-mining conditions refer to those prior to the advent of large mine inflows beginning in 1999. Even these water level data are sparse, however, and HCI (2003) included in the compilation some estimates of pre-mining conditions projected from post-mining drawdown trends in recently constructed monitoring wells. Other pre-mining water levels were rejected by HCI because of documented damage to wells resulting in eccentric water level measurements. Most water levels included in the

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compilation represent conditions in the LOB (or equivalent coal) and in the first sandstone below the LOB. Some deep wells, particularly in the far northern part of the HSA, were screened in the uppermost Starpoint Sandstone units.

The compiled pre-mining water-level data are plotted and have been contoured in Figure 5. This interpretation indicates that ground water in the deep aquifer (i.e., in the LOB coal and underlying sandstones) generally flows from south-southwest to north-northeast beneath the Skyline Mine. The pre-mining ground-water gradient indicated in Figure 5 ranges from about 0.03 ft/ft in the northern part of the HSA to as low as 0.009 ft/ft in the area around the Skyline Mine.

This interpreted pre-mining potentiometric surface indicates that the majority of recharge to the deep system probably occurs in the southwest of the HSA, in the high country south of Huntington Reservoir. Discharge must occur downgradient, in the direction of Scofield Reservoir. As discussed in HCI (2003), there is yet no direct evidence from stream or spring gaging of the actual location of the ground-water discharge. Because of the major stratigraphic offsets, it is considered unlikely that the ground water would continue flowing northeastward through the Fish Creek and Pleasant Valley grabens. It is more likely that discharge is diffuse, and occurs beneath the alluvium and marshes of Scofield Reservoir, and is thus ungaged.

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#### 2.6 PUMPING AND GROUND-WATER DISCHARGE TO MINE

#### 2.6.1 Mine Inflows

The Winter Quarters tract was mined from the turn of the century through the 1930's, and the workings were reportedly relatively dry (although detailed inflow data do not exist). The Skyline Level 3 Mine lies to the south and west of the old Winter Quarters Mine, and was worked from 1982 through 1996. The Level 3 Mine also encountered very little ground water, at least relative to the later inflows to the Level 2 Mine. The so-called "large" inflows in the Level 3 Mine ranged from 100 to 300 gpm, and they usually decreased over several weeks to 10 gpm or less. Mining in the Level 1 Mine (directly above the northeast half of Level 2 Mine) also encountered little ground water during the period 1989 through 1998. Consequently, from 1982 to 1999, the total discharge of ground water to the Skyline Mine ranged between 200 and 500 gpm. Mining in Level 2 of the Skyline Mine began in 1996 and continues to present. Large, persistent inflows were first encountered in Level 2 beginning in 1999. Figure 6 shows the increases in ground-water inflows to the Level 2 workings from March 1999 through April 2003.

Mining encountered an inflow of 1,600 gpm from the floor of the entry in the 14-Left headgate in March 1999 (Plate III). In December of the same year, another similar inflow of 1,200 gpm was encountered in the 16-Left headgate. A third large inflow of about 1,000 gpm was encountered in the West Submains crossing of the Diagonal Fault in March 2001.

Mining in the 10-Left area encountered a sudden inflow of about 1,200 gpm issuing from a fracture zone in the walls and floor of the entry on August 9, 2001. Seven days later, mining in an adjacent entry encountered an additional 2,700 gpm from the same structure. The combined inflows to the two entries comprise the nominal 10-Left inflow. The total rate of inflow at 10-Left increased to about 6,500 gpm for a short time during the drilling of a nearby

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large-diameter well, but decreased back to about 4,200 gpm when the well was grouted. Since mid-September 2001, the 10-Left inflow has declined to less than 3,000 gpm.

Mining west of the Diagonal Fault since September 2001 encountered some additional significant inflows in the East Submains (initially 1,000 gpm), and at three other locations associated with three parallel faults cutting the 11-Left panel (Plate III). The 11-Left inflows initially totaled 3,500 gpm, but temporarily increased as longwall mining exposed a long reach of one of the faults.

Flow rates of the individual large, Level 2 inflows have only occasionally been measured directly. More commonly, flow rates have been estimated from power usage of pumps and by stage-volume observations in the flooding mine workings. Waters from the individual inflows since about September 2002 have flowed together in several locations, and the flow rates have since been estimated from the manifolded pumpage. Table 3 summarizes the dates when first encountered, the elevations, and both the initial and March 2003 inflow rates for the largest and relatively sustained inflows to the Level 2 Mine. The total inflow based on metered mine discharge in February 2003 was 7,850 gpm.

Descriptions of the physical characteristics of the inflows and the chemistry of the inflowing water are provided in HCI (2003). Two kinds of inflows have been encountered in the Skyline Mine. The most common, which have occurred in all three levels of the mine, discharge from the roofs of the entries, usually from channel sandstones lying immediately above the coal. These inflows typically decrease significantly and often "dry up" within a few weeks. The second kind -- the large inflows to the Level 2 workings from the floor and walls of the workings -- do not decrease appreciably with time. All of the large inflows to the Level 2 workings are associated with north- to northeast-trending faults of relatively little vertical or lateral displacement.

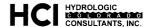


The chemistry of the large inflows to the Level 2 workings has been compared extensively to the chemistry of surface-water samples from streams, springs, and Electric Lake (HCI, 2001; Mayo Associates, 2002). Both the major ion and isotopic compositions are significantly different in the mine water than in the surface waters. In addition, analyses of <sup>14</sup>C content clearly indicate that the waters from the mine and Electric Lake are of different ages. Tritium (<sup>3</sup>H), which was released in large quantities to the atmosphere during the above ground testing of nuclear bombs in the early 1950s, is present in most surface and shallow ground waters throughout the world. Consequently, tritium concentrations have been analyzed in numerous surface- and ground-water samples since the initial inflow at 10-Left began. Samples from Electric Lake have consistently contained tritium in the range of 8 to 12 tritium units (TU). The tritium content of the mine inflow samples and the discharge of well JC-1 indicate tritium in the range of 1 to 2 TU. Thus, the tritium analyses of inflow and pumping samples suggest that these contain deep ground water with only a small component of water that originated at or near the surface.

Temperature provides another clear distinction between near-surface water and the mine inflows. The temperature of the water in the deeper parts of Electric Lake is about 9.6°C. The ambient temperature of the Level 2 Mine is about 8.9°C, and the temperatures of the relatively small inflows coming from channel sandstones in the roof of the mine and other roof "drips" has also averaged about 8.9°C. In contrast, the temperatures of the large, persistent inflows range from 13.2° to 15.9°C. Mayo and Associates (2002) conclude that these higher temperatures indicate the source of the large inflows might be 600 to 1,000 ft below the level of the workings.

#### 2.6.2 Pumping from Dewatering Wells

During September and October 2001, two large diameter wells -- designated JC-1 and JC-2 -- were drilled from the surface immediately above the inflow in 10-Left in an attempt to



intercept as much of the ground water as possible before it flowed into the mine. Both wells were drilled in James Canyon in Section 35, T13S, R6E (Plate III). Drilling methods, geological intercepts, and well completions for both wells are described in detail in HCI (2002a). Both JC-1 and JC-2 were completed in the Storrs Sandstone; JC-1 in a highly-porous splay of the Diagonal Fault, and JC-2 in an unfractured zone. Because of disappointingly low yield, JC-2 has not been pumped for any significant length of time. The historic pumping of JC-1 is shown in Figure 7.

A third dewatering well was completed into the 10-Left workings in April of 2003. JC-3 pumps directly from the pool of standing water in the mine workings; and, thus, has only a small, indirect effect on ground-water flow. Consequently, well JC-3 is not simulated in the model.



### 3.0 CONCEPTUAL HYDROGEOLOGIC MODEL

The available geologic, hydrologic, and climatologic data were incorporated into a conceptual hydrogeologic model that describes the surface-water and ground-water flow systems within the HSA. The conceptual hydrogeologic model is the descriptive physical analogue of the hydrologic system that the numerical model (described below) mathematically simulates. The essential components of the conceptual model include:

- hydrologic boundaries (ground-water divides, rivers, major aquacludes, etc.),
- the areal and vertical extent and hydraulic characteristics of the primary hydrogeologic units,
- hydrologically significant structures (i.e., faults),
- recharge to the HSA,
- perennial streams and reservoirs, and their interaction with the regional ground-water system,
- ground-water pumping (including mine inflows),
- mining and its hydrologically-significant consequences,

The following paragraphs describe the principal conceptual components. Section 4.0 will describe how these components have been incorporated into or used to calibrate the numerical model.

#### 3.1 HYDROSTRATIGRAPHIC UNITS

Eleven geologic units, shown in the hydrostratigraphic column in Figure 8, have been differentiated in the HSA. In general, from shallowest to deepest, they are:

1) Overburden,

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- 2) Upper O'Connor seam (UO),
- 3) Interburden 1,
- 4) Lower O'Connor B seam (LOB),
- 5) Interburden 2,
- 6) Storrs Sandstone,
- 7) Interburden 3,
- 8) Panther Sandstone,
- 9) Interburden 4,
- 10) Starpoint Sandstone, and
- 11) Mancos Shale.

The Mancos shale is discretely represented only where it crops out in lower Huntington and Left Fork Canyons; elsewhere, it is implied as the basement to the ground-water flow system with a very low hydraulic conductivity. Furthermore, the overburden and Starpoint units are divided into multiple layers in the model. Consequently, the model incorporates a total of 13 layers.

The sections below describe the available test data and other bases for estimating the hydraulic properties of the various hydrostratigraphic units. The hydraulic properties of all hydrostratigraphic units used in the model are summarized in Table 4.

#### 3.1.1 Overburden and Interburden units

Overburden comprises the top two geologic layers of the model, which together locally represent over 2,000 ft of Blackhawk Formation siltstones and shales. Differentiation of the thin upper unit from the much thicker lower overburden is necessary in order to model an uppermost zone with a much greater hydraulic conductivity (Mayo and Morris, 2000) than the materials below. As shown in Figure 8, the lower overburden is subdivided into two to four model layers,



depending on location (two where UO coal is modeled, and four where the UO coal layer does not exist). The additional model layers are necessary to model the propagation of fractures upward into overburden as mining progresses. A relatively low value of hydraulic conductivity is assigned to the lower overburden.

Few data are available on the hydraulic properties of the overburden. Laboratory permeability tests of cores of the Blackhawk shales and siltstones conducted by DOGM (2001) indicated values of both horizontal and vertical hydraulic conductivity (K) on the order of  $10^{-8}$  ft/day to  $10^{-7}$  ft/day, respectively. It should be recognized, however, that laboratory tests are conducted on intact samples of core and do not reflect the contributions of fractures or bedding plane discontinuities to the bulk hydraulic conductivity of the formation. Thus, laboratory tests of cores almost always yield values of K much lower than values determined by hydrologic testing of the bulk material in the field.

In the model, the lower overburden unit, which represents the bulk of the Blackhawk Formation, is assigned a horizontal hydraulic conductivity ( $K_h$ ) value of  $10^{-3}$  ft/day. The vertical hydraulic conductivity ( $K_v$ ) is assigned a value of 4 x  $10^{-4}$  ft/day. These values are as much as 4 orders of magnitude higher than the values derived from core tests. However, in order to conservatively allow for the greatest possible migration of water from the surface to depth, high, but still reasonable, values of  $K_h$  and  $K_v$  were chosen. These values are the highest that could be assigned in the model without simulating significant drawdown in shallow monitoring wells that, in the field, show no drawdown.

The upper overburden in the model (modeled as approximately 150 ft thick) is assigned much higher  $K_h = K_\nu$  values 1 ft/day. (The uppermost layer is assumed to be isotropic.) These high values allow through-flow of shallow ground-water recharge to match streamflows. This very permeable surface layer represents the zone where weathering and stress-relief fracturing have resulted in enhanced hydraulic conductivity, and is commonly referred to as the "active zone" of ground-water movement (Mayo and Morris, 2000).

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In transient runs, the lowest of the multiple layers representing lower overburden is locally converted to a higher-conductivity material representing fractured and collapsed "gob" above the mined coal. The gob is approximately 100 ft thick (8 times the thickness of the coal) and is assigned K values 10 times greater than the values in the lower overburden. The four interburden layers (between the coals and the sandstones) also represent shales and siltstones. The first interburden is assigned properties similar to the lower Blackhawk overburden unit. The lower three interburden layers having a slightly lower vertical hydraulic conductivity.

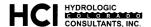
#### 3.1.2 Coals and Upper Sandstones

Two coal units (the UO and LOB) are simulated in the model. The upper coal is differentiated in order to account for early mining and mine inflows. The two coal units are assumed to have relatively high horizontal hydraulic conductivity (similar to a sandstone) and to be isotropic, the result of fractures or cleats.

The Storrs and Panther Sandstones are modeled as separate units, with interburden between. A relatively high hydraulic conductivity of 1 ft/day is assigned to the Storrs and Panther sandstones based on the results of pumping in James Canyon (HCI, 2003). Both sandstones are assumed to be isotropic, resulting from the offsetting effects of bedding plane discontinuities and high-angle fractures.

Vaughn Hansen Associates (1982) conducted a series of short-duration, single-well drawdown recovery tests in the Lower O'Connor coal and Aberdeen Sandstone (equivalent to the combined Storrs/Panther sandstones) beneath lower Winter Quarters Canyon. They estimated the hydraulic conductivity of the coals and underlying sandstones to range from 1 to 3 ft/day. These values would, of course, reflect aquifer conditions in only a relatively small area around the well screens. Nevertheless, HCI considers the values to be reasonable for

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moderately fractured, partially cemented, fine-grained sandstone. These K values are similar to values derived more recently by HCI (2003).

### 3.1.3 Starpoint Sandstone

Kravits (2003) found that the Starpoint Formation varies in thickness and composition across the HSA. Beneath the Skyline Mine, it consists of at least 10 stacked sandstones, with a combined thickness of 1,200 ft, separated by siltstone/shale units. The thickness of the entire formation is about 1,500 ft thick. For simplicity, the formation is modeled as a homogenous unit with thickness varied from 500 to 1500 ft, bulk properties of K and specific storage ( $S_s$ ) that account for both the sandstone and shale components, and a horizontal/vertical anisotropy ratio of 5:1. The Starpoint hydrostratigraphic unit is divided into upper and lower numerical layers in the model in order to avoid a very thick element above the bottom boundary of the model.

Laboratory permeability tests of cores of the Starpoint Sandstone conducted by DOGM (2001) indicated both horizontal and vertical K values to be on the order of 0.01 ft/day. As described previously, however, laboratory tests conducted on intact samples of core do not accurately reflect the contributions of fractures to the overall hydraulic conductivity, and therefore, generally yield values of K much lower than values determined by hydrologic testing of the bulk material in the field.

HCI (2003) estimated the average, or bulk, parameters for the Starpoint Formation using several analytical techniques to evaluate long-term pumping and monitoring data. The bulk K in the vicinity of Skyline Mine was found to be about 2 ft/day, and the specific storage was found to be about 6 x  $10^{-6}$  ft<sup>-1</sup>. These hydraulic conductivity values are derived primarily from responses in monitoring wells and pumping wells within the zone of north-south fracturing that is the location of all major mine inflows in the Skyline Mine. Conversely, HCI

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assumes K values of about 1 ft/day in the Starpoint Formation outside of the zone of north-south fracturing (to the north), where historic inflows were much smaller.

### 3.2 HYDRAULIC CONDUCTIVITY OF FAULTS AND FRACTURES

Plate II shows the structures that are included in the conceptual hydrogeologic and numerical ground-water models. Within the model, these structures have been differentiated into:

- 1) large-displacement, bounding faults,
- 2) intermediate-displacement faults, and
- 3) small-displacement faults.

The Gooseberry, Fish Creek, and Pleasant Valley Faults are so-called large-displacement faults with displacements on the order of many hundred to several thousand feet. They influence the movement of ground water by offsetting hydrogeologic units of significantly different hydraulic characteristics. In each case, the faults juxtapose relatively permeable Starpoint sandstones against the lower-permeability Blackhawk Formation (Kravits, 2003). Consequently, these model-bounding faults are assumed to prevent lateral ground-water flow throughout the entire model thickness, and as will be discussed in Section 4.3, are assumed to be no-flow boundaries. However, because of presumed brecciated zones associated with the faults, water can move vertically within the fault zones.

The relative hydraulic conductivity of the small- and intermediate-displacement faults in the interior of the HSA is assumed to be a function of both a) the magnitude of displacement and b) the hydraulic conductivity of the stratigraphic unit through which the structure cuts. In general, it is assumed that smaller-magnitude displacements (i.e., less than about 200 ft) result in more open, broken fault zones, and larger-magnitude displacements (those greater than 200 ft) result in gouge-filled, low-permeability fault zones. Furthermore, sandstones and coals are

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presumed to undergo brittle deformation within the fault zones whereas the siltstones and shales behave plastically. Consequently, a small- to intermediate-displacement fault is characterized by relatively high hydraulic conductivity in the deep sandstone-dominated units and relatively low hydraulic conductivity in the Blackhawk Formation units.

The small-displacement faults within the model domain, shown in Plates II and III, include the West Mains, Gooseberry South, Diagonal, 16-Left, 14-Left, and 11-Left-a, 11-Left-b, and 11-Left-c Faults. All large, persistent ground-water inflows in the Skyline Mine to date have been associated with these faults. Except as described below, the small-displacement faults are assigned  $K_h$  values of 0.001 ft/day in their upper portions (within the overburden) and  $K_h$  values of 1.0 ft/day within the sandstone units (below the LOB). The Diagonal Fault is assigned a  $K_h$  value in the sandstone of 10 ft/day generally, and 20 ft/day beneath the mine. As will be described in more detail in Section 5.1, the upper portion of the Diagonal Fault was assigned a range of K values under Electric Lake in the sensitivity analysis of the possible impact to Electric Lake during mining (Section 5.1).

The intermediate-displacement faults within the model domain include the Valentine, O'Connor, and Connelville Faults. The hydraulic properties of these larger interior faults control the ground-water flow directions, and in predicting the flow of ground water from potential sources to the inflow points in the Skyline Mine.

The Valentine Fault is assumed to localize as much as 1,400 ft of vertical displacement across its trace. Consequently, it and its southern extensions are modeled as barriers to horizontal ground-water flow (Plate IV).

Direct evidence bearing on the relative hydraulic conductivity of the O'Connor Fault is sparse. In their detailed study of streamflows and water chemistry in Eccles Creek and tributaries, Vaughn Hansen Associates (1979) found a significant increase in flows where streams crossed the O'Connor Fault. Water chemistry data also indicated changes where the

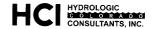


streams cross the fault. These observations have been interpreted to suggest that the O'Connor Fault is relatively open and transmissive (Vaughn Hansen Associates, 1979; HCI, 2003). In fact, however, the discharge of ground water of deep-aquifer chemistry along the fault zone more strongly suggests up-welling against an aquaclude, and that the O'Connor is, at least in the Eccles Creek drainage, a barrier to horizontal ground-water flow. This interpretation is consistent with the large (600 ft) vertical displacement of the O'Connor Fault north of Electric Lake, and with a presumed broad damage zone along that portion of the fault. The O'Connor Fault south of Electric Lake shows only about 100 ft of vertical displacement. HCI assumes that along this portion of the fault the K is relatively high where the fault cuts sandstone units (Plate IV).

Although available evidence is somewhat ambiguous, the relative hydraulic conductivity of the Connelville Fault might be opposite to that of the O'Connor Fault. North of Electric Lake where vertical displacement is great on the O'Connor Fault, the vertical displacement on the Connelville Fault is as small as 200 ft. Along this reach of the fault Vaughn Hansen Associates, in the study described above (1979), found no indication of any up-welling of ground water where the Main or South Forks of Eccles Creek cross the Connelville Fault. This suggests that the Connelville Fault does not impede horizontal ground-water flow along its reach north of Electric Lake, and therefore might be a relatively conductive structure. Conversely, numerous encounters with the Connelville fault in the Skyline Mine have generated only a few hundred gpm of ground-water inflow. In the White Oak Mine and Belina No. 1 Mine (Figure 1), relatively large initial inflows at Connelville Fault crossings were found to decrease rapidly over short periods of time (DOGM, 2001; Vaughn Hansen Associates, 1979). These encounters suggest that the Connelville Fault might not be a highly-conductive structure.

Nevertheless, for the purpose of constructing a conservative model, HCI assumes that the Connelville Fault, where it cuts the deep units beneath and north of Electric Lake, is characterized by high K values (Plate IV). South of Electric Lake the vertical displacement of the

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Connelville Fault increases greatly, to as much as 1,200 ft. For that reason, the horizontal hydraulic conductivity of the fault zone south of Electric Lake is assumed to be low.

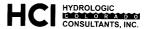
Figure 10 shows the three intermediate-displacement interior faults, and the relative displacement and concomitant relative permeabilities along their traces. The hydraulic properties of all faults used in the model are shown in Table 5.

## 3.3 HYDROLOGIC BOUNDARIES

The boundaries for the Skyline numerical model have been selected to coincide with natural hydrologic boundaries to limit the amount of ground-water and surface-water flow that naturally enter and exit the HSA. The eastern and western boundaries (Plate IV) are defined by the Pleasant Valley and Gooseberry Faults, respectively. As previously described, both of these regional faults juxtapose the Starpoint sandstones against thick sequences of much lower permeability siltstones and shales. The northern boundary of the model limit is the south fault of the Fish Creek graben, currently assumed to be located in Fish Creek Canyon. All of these boundaries are assumed to be no-flow boundaries (i.e., there is no lateral inflow or outflow across them).

The southwestern model boundary is defined by a surface-water divide along the high ridge west of Joe's Valley and the divide below Paradise Creek Valley. It is assumed that the surface-water divide corresponds to a ground-water divide that also creates a no-flow ground-water condition. The southeastern model boundary follows the channel of Left Fork and is also assumed to be a no-flow boundary as a result of the Mancos shale (with very low hydraulic conductivity) being exposed in the creek bed along this reach. Scad Valley (in northeastern Joes Valley) is not included in the model, because it is hydrologically isolated from the model domain by the Valentine Fault and the outcropping of Mancos shale in Left Fork.

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### 3.4 GROUND-WATER RECHARGE

Recharge to the ground-water system includes shallow-circulating ground water, which re-emerges in the surface-water system, and a much smaller component of deeply circulating ground water. Recharge to large hydrologic basins in the western U.S. is commonly estimated using the Maxey-Eakin method (Avon and Durbin, 1994). The Maxey-Eakin method assigns recharge coefficients (actually fractions of the yearly precipitation) to zones defined by rates of precipitation. In the HSA for the Skyline mine, however, all areas fall into just one Maxey-Eakin precipitation zone -- the zone representing upland recharge with greater than 20 inches of yearly precipitation. The Maxey-Eakin coefficient for this zone is 25 percent. Utilizing this factor in the Skyline model applies such a large volume of recharge in the HSA that the model could not be calibrated using any reasonable set of hydraulic properties. Zhu (2000), Greenslade (2000), and others have argued that the Maxey-Eakin method can greatly overestimate recharge in studies dominated by high elevation and areas of relatively high precipitation, particularly in areas such as the Skyline HSA where bedrock is predominant over alluvium. Consequently, HCI resorted to a more empirical method, somewhat similar to the Maxey-Eakin method, to estimate local ground-water recharge.

For this investigation, the volume of total recharge is assumed to be approximately equal to the volume of shallow recharge which in turn is assumed to be approximately equal to the volume of water that discharges to all of the streams in the HSA under baseflow conditions (the average October flow as described in Section 2.4). The recharge (in ft/yr) to the shallow ground-water system beneath each sub-basin in the HSA was calculated simply as the recorded baseflow (ft³/yr) in the sub-basin divided by its area (ft²) as planimetered on U.S. Geological Survey (USGS) topographic maps. By estimating the average elevation of each sub-basin (again, using USGS topographic maps), an orographic relationship was then developed to calculate ground-water recharge as a function of elevation (Figure 9). It should be noted that only four moderately sized sub-basins in the HSA were found to have long-term USGS streamflow data (Table 1). Some other streams in the HSA (e.g., Mud Creek, Fish Creek)



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have long-term flow data, but their basins encompass very large ranges in elevation. Unfortunately, several other important streams, including upper Huntington Creek and Left Fork, have insufficient gaging records; and they could not be used.

Linear regression analysis of the data shown in Figure 9 yields the relationship:

$$R = (0.00045 \cdot z) - 3.66 \tag{2}$$

where:

R = long-term average annual recharge to ground water (ft/year), and z = average elevation of land surface (ft, NGVD).

This relationship can then be used to estimate recharge for areas with different elevations within the HSA.

For comparison, Maxey-Eakin recharge coefficients back-calculated from the results of this more local and empirical approach range from about 6 percent to about 15 percent for the four basins whose average elevations and annual precipitation range from about 8,400 ft and 24.3 inches to about 9,000 ft and 30.6 inches, respectively.

By virtue of the relatively high hydraulic conductivity assigned to the thin, uppermost layer in the model (described in Section 3.1.1), the majority of the shallow recharge calculated above is discharged to the local streams. A small component infiltrates downward to recharge the deeper ground-water system. The volume of this deeper recharge is a function of the vertical hydraulic conductivity of the lower overburden, and it was estimated during the steady-state calibration (described in Section 5.1).



## 4.0 <u>DESCRIPTION OF NUMERICAL MODEL</u>

### 4.1 NUMERICAL CODE USED IN STUDY

In this report the term "code" or "numerical code" is used to refer to a computer program that solves a system of equations that describe a ground-water flow problem. The term "model" or "numerical model" refers to a specific combination of a code, a finite-element mesh, hydrologic data, and boundary conditions that describe a specific set of site conditions. The term "numerical model" should not be confused with the previously described "conceptual hydrogeologic model" which is a qualitative description of the physical ground-water flow system simulated by the numerical model.

The numerical modeling described in this report utilizes the numerical code *MINEDW* that solves three-dimensional ground-water flow problems with an unconfined, or phreatic, surface using the finite element method (HCI, 1993). This code was developed and copyrighted by HCI (Timothy J. Durbin, P.E., was the primary author) to solve problems related to mine dewatering. Its special attributes specifically related to mine hydrology are described by Azrag et al. (1998). *MINEDW* has been validated by Sandia National Laboratories for the U.S. Bureau of Land Management as part of the EIS process for several gold mines in Nevada (Sandia National Laboratories, 1998).

#### 4.2 MODEL GRID AND DISCRETIZATION

The current Skyline model domain encompasses approximately 140 mi<sup>2</sup>, and the finiteelement grid contains 32,172 nodes and 58,188 elements within 13 layers (Figures 10, 11, 12, and 13). The grid is most finely discretized in the area of the existing mine and Electrical Lake to:

• Refine numerical solutions of hydraulic heads and flows near the area of flow convergence, and

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• More reasonably represent the geometry of the mine, location of the major ground-water inflows (Figure 14), and the location of pumping well JC-1.

The finite-element grid has also been discretized to incorporate the key hydrogeologic features of the HSA including the sandstone outcrops near the eastern boundary of the model, the location and orientation of the faults (Figure 14), and various surface-water bodies. In the detailed mine area, the minimum horizontal dimension of an element is in the range of about 600 to 800 ft (Figures 10), and the thickness of layers ranges between approximately 10 and 900 ft (Figures 12 and 13).

## 4.3 MODEL BOUNDARIES

As introduced in Section 3.2, all of the model boundaries are assumed to be no-flow boundaries (Figure 10) as defined by:

- 1) The trace of the Gooseberry fault to the west. As described in Section 3.2, this fault zone is not explicitly incorporated into the model because of the great depth to the Starpoint sandstone in that area. The sandstone is the only unit that presumably would impart any significant hydraulic conductivity to the fault zone.
- 2) The Pleasant Valley fault to the east,
- 3) The southernmost Fish Creek fault to the north,
- 4) A topographic divide to the southwest, and
- 5) The Left Fork of Huntington Creek to the southeast.

Although they are no-flow boundaries to lateral flow, both the Pleasant Valley and Fish Creek faults are incorporated into the model as specific zones of enhanced vertical hydraulic conductivity that enable discharge from the deep aquifer system to the streams. Even though Fish Creek and the Left Fork of Huntington Creek coincide with no-flow boundaries, the





streams themselves were simulated as drain nodes within the first layer of the model that enables ground-water discharge (to be described below).

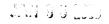
The model is constructed such that all ground water within the model domain is generated by recharge from precipitation. Most of the recharge discharges back into the streams through the uppermost (assumed to be 150-ft thick) permeable portion of the Blackhawk Formation or sandstone layers where they crop out at the ground surface.

A small portion of the recharge reaches the deep aquifer system, especially at the southwestern part of the model, where:

- a) The upper Starpoint sandstone is relatively close to the ground surface, and
- b) Recharge from precipitation is relatively large due to high surface elevations.

Ground water within the deep system flows from south to north between the Gooseberry and Connelville faults (where it is tight) and between the Gooseberry and O'Conner faults where the Connelville fault is open. The deep ground-water system then discharges at the north-northeastern boundary where the Starpoint Sandstone is relatively close to the ground surface and there is a zone of enhanced vertical hydraulic conductivity associated with the Fish Creek and Pleasant Valley faults.

The bottom of the model is defined as the contact between the Starpoint Sandstone and the Mancos Shale with the exception of the bottom of Huntington and Left Fork Canyons, where the Mancos Shale is exposed at ground surface (Plate IV). This bottom boundary is defined as a no-flow boundary throughout the entire model domain.





#### 4.4 SIMULATION OF HYDROLOGIC FEATURES

## 4.4.1 Simulation of Hydrogeology

In the finite-element method, hydraulic properties are assigned to elements; and hydraulic heads and fluxes are associated with nodes. Therefore, every element in the model is assigned to a model "zone" with specified values for horizontal ( $K_1$ ) and vertical ( $K_2$ ) hydraulic conductivity, specific storage, and specific yield (which is only utilized if the element contains the water table). There are 38 zones with different hydraulic parameters -- 14 for hydrogeologic units and 24 for faults -- incorporated into the model. The distribution of the 14 hydrogeologic units between 13 model layers and their relationship with the conceptual hydrostratigraphy is shown in Figure 8. The various hydrogeologic zones are shown in map view (for the uppermost layer) and in east-west and north-south cross-sections in Figures 11 through 13, respectively.

The hydraulic properties of the various hydrogeologic units in the model are summarized in Table 4. Some of the hydrogeologic units (e.g., the coals and the Storrs and Panther sandstones) are considered to be isotropic (i.e.,  $K_h = K_z$ ), but most of the sedimentary units have been made anisotropic with the general relationship  $K_h > K_z$ . This horizontal-to-vertical anisotropy is used to represent the effects of the interlayering of materials of higher and lower hydraulic conductivity.

### 4.4.2 Simulation of Faults

Ten faults are incorporated into the model (Figure 10) as discrete zones ranging from 100 to 400 ft wide:

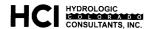
- 1) Diagonal,
- 2) 14-Left,
- 3) 16-Left,
- 4) Connelville (northern and southern portions),



- 5) O'Connor (northern and southern portions),
- 6) Valentine,
- 7) Gooseberry South,
- 8) Fish Creek,
- 9) Pleasant Valley, and
- 10) West Mains.

The fault elements adjacent to the overburden and any other materials above the LOB seam -- referred to as the "upper part" -- are simulated with a relatively very low hydraulic conductivity with the general relationship  $10K_h = K_z$  with the exception of the Fish Creek and Pleasant Valley faults, which are open within the overburden to allow all ground water at the northern boundary to discharge to Fish Creek and tributaries of Mud Creek. As explained in Section 3.2, the fault elements adjacent to all units below the top of the LOB seam (the coal, the interburden, and the sandstones) -- referred to as the "lower part" -- are simulated differently depending on the magnitude of displacement on the fault. The intermediate-displacement faults within the model domain are simulated with very low hydraulic conductivities in both the upper and lower parts. However, the small-displacement faults within the model domain are assumed to be highly conductive where they cut relatively brittle sandstone and coal (lower part), but essentially non-conductive where they cut more plastic, fine-grained sedimentary units. The hydraulic properties of the various faults simulated in the model are summarized in Table 5.

The 10-Left fault, which produces the largest inflow where it is intersected by mining within the LOB, is possibly a splay of the Diagonal fault; but in any case, it is not well-defined hydrogeologically. This fault appears to be relatively well connected to the Diagonal Fault further to the south along the fault plane (based on the response of piezometer 9-Left corehole), but not so to the Diagonal Fault immediately to the west, laterally through the Storrs and Panther Formations (Figure 14). This complex stratigraphic/structural relationship is further demonstrated by the fact that pumping from well JC-1, which is completed into the Storrs Sandstone within or immediately adjacent to the Diagonal Fault, has not had a major effect on reducing the inflow at 10-Left. These conditions were simulated in the model using the *FAULT* subroutine of *MINEDW* that links individual nodes with a high transmissivity. In this case, the



five nodes simulating the LOB along the 10-Left fault were "fault-linked" vertically to the underlying Starpoint sandstones, and then five vertical columns were linked horizontally between each other and to the Diagonal fault to the south.

As will be discussed further in Section 4.6, fault linking was also used to simulate the three inflows at 11-Left-x24, 11-Left-x40, 11-Left-SU, and East Mains by a single node column.

# 4.4.3 Simulation of Recharge

Recharge to the ground-water system from precipitation was applied to each element on the top layer of the model by using the empirical relationship between recharge and surface elevation described in Section 3.3.4.

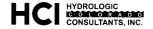
In both the steady-state and transient modes, long-term average precipitation was simulated (i.e., precipitation was not varied with time to reflect either seasonal or longer-term variations). Initially, time-variable recharge had been used for the transient calibration using actual monthly historical precipitation for each monthly time step in the model. However, those simulations showed that model-calculated gains and losses in Electric Lake attributable to variations in precipitation were great enough to mask any possible small losses attributable to mining. Hence, this "noise" in the model predictions was removed by using long-term average precipitation.

## 4.4.4 Simulation of Surface-Water Bodies

The streams, reservoirs, and springs were incorporated into the ground-water flow model. Streams and springs in the HSA are simulated using drain nodes along the courses of the streams with discharge calculated from the relationships:

$$Q = C_L (H_s - H_c) \quad \text{if } H_c > H_s \tag{3a}$$

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or

$$Q = 0 \quad if \ H_c \le H_s \tag{3b}$$

where

Q = ground-water discharge to the stream or spring (cfs),

Hs = specified elevation of stream (ft),

Hc = model-calculated elevation of water table (ft), and

 $C_L$  = leakance factor for the stream/spring node (ft<sup>2</sup>/s).

The model incorporated 483 drain nodes to simulate Fish Creek, Mud Creek and Huntington Creek, and their numerous tributaries. Another 31 drain nodes were incorporated into the model to simulate springs along the Starpoint Sandstone/Mancos Shale contact along Huntington and Left Fork Creeks in the areas where the Mancos Shale crops out at the ground surface.

The drain nodes for both the streams and springs were assigned elevations based on the USGS topographic maps of the area. The fluxes from these drain nodes (calculated by either Equation 3a or 3b) are then summed to obtain a value for ground-water discharges to the various streams that can be compared to the measured baseflow data. As indicated in Equation 3b, the drain nodes streams and springs, which can only discharge from the ground-water system, are "turned off" when the calculated water table falls below their specified elevation.

Electric Lake is simulated in the model with constant-head nodes. The use of constant-head nodes instead of drain nodes allows the lake to gain ground water if the calculated water table in the adjacent formations exceeds the lake elevation and to lose water if the water table is below the lake elevation. Electric Lake was simulated with 52 such constant-head nodes. Initially, Electric Lake had been simulated in the model with variable (but still specified) head nodes reflecting historic lake-stage records. As with variable precipitation, the early transient calibration runs showed that water gains and losses attributable to the changing lake stage could





significantly mask any possible small losses attributable to mining. Consequently, a long-term average lake stage of 8,560 ft was used in all further simulations.

### 4.5 SIMULATION OF MINING

Ground-water inflow induced by mining is simulated by assigning as drain nodes the nodes representing the bottom of the coal seam (either the UO or LOB) in the area being mined. Each drain node has a leakance factor calculated by:

$$C_L = \frac{K_m \cdot L \cdot w}{h} \tag{4}$$

where

 $K_m$  = hydraulic conductivity of material [m/day],

L = dimension of element [m],

w =width of area [m], and

b = thickness of "membrane" [m].

The value of  $K_m$  is an input value, L is a function of the grid discretization, and w/b (the so-called "connectivity factor") is a value obtained through transient calibration. Development of the three mining areas since 1982 was incorporated into the model with 391 such drain nodes. The calibrated connectivity factor for the mining nodes was 0.003.

In the numerical simulations, the hydraulic conductivity of the approximately 100-ft thick subsidence zone above a mined panel was increased by a factor of 10 in appropriate time steps (as described in Section 3.0). The longwall operations have been represented by 481 elements in the model and are simulated on a yearly basis according to mine plans provided to HCI by CFC.

#### 4.6 SIMULATION OF PUMPING AND MAJOR GROUND-WATER INFLOWS

Pumping from well JC-1 is simulated explicitly in the model by a pumping node located on the Diagonal Fault in the Panther Sandstone layer. It should be noted that JC-1 was actually

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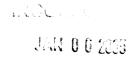


completed into the Storrs Sandstone within or immediately adjacent to the Diagonal Fault. In the model, the relatively very large hydraulic conductivity (20 ft/day) in the fault zone puts the Storrs and Panther sandstones in direct hydraulic connection. Therefore, the pumping node has been assigned to the lower Panther Sandstone interval). During the predictive runs, the pumping node is converted to a constant head node when the calculated water level reaches the elevation of the top of the Panther sandstone. This numerical approach enables the reduction in the pumping rate of JC-1 due to dewatering of the deep ground-water system to be replicated.

Well JC-2 was not incorporated into the model due to its insignificant pumping rate and short duration of. Pumping from JC-3, which is simply removing water that has already flowed into the flooded underground workings in the 10-Left areas, has no significant effect on the calculations of ground-water inflow. Consequently JC-3 is also not simulated in the model.

The major ground-water inflows are all explicitly simulated by specific drain nodes. The 14-Left, 16-Left, and 10-Left inflows were simulated along the appropriate faults incorporated into the model (Figure 14). The East Mains, 11-Left-x24, 11-Left-x40, and 11-Left-SU inflows were simulated as discharges from four localized and separate faults that were incorporated into the model by single columns of "fault-linked" nodes with high transmissivity hydraulically connecting the LOB coal with Starpoint Sandstones. The calibrated connectivity factors (described by Equation 4) for each of these drain nodes are summarized in the following table: following:

Inflow	Connectivity Factor		
14-Left	incrementally decreased from 20 to 0.4		
16-Left	incrementally decreased from 2.5 to 0.1		
10-Left	100		
East Mains	3.5		
11-Left-x24	0.7		
11-Left-x40	0.9		
11-Left-SU	0.5		



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It should be noted that to replicate the 14-Left and 16-Left inflows, their connectivity factors were decreased in time. The East Mains, 11-Left-x24, 11-Left-x40, and 11-Left-SU inflows were replicated reasonably well using constant connectivity factors.

To replicate the largest ground-water inflow, the 10-L inflow, the leakance factor defined by Equation 4 was slightly modified to:

$$C'_{L} = \frac{C_{L}}{\sqrt{\Delta h}} \tag{5}$$

where

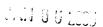
 $C_L$  = leakance factor from Equation 4, and

 $\Delta h = \text{magnitude of change in hydraulic head dynamically calculated by model.}$ 

Equation 5 is valid for large ground-water flows that are "throt tled" by either non-Darcian flow or by convergence of flow to a small diameter drainhole or fracture that intersects this flow (Azrag et al., 1998). The model-calculated discharge at 10-Left was calibrated to the measured inflow by using Equation 5 with a connectivity factor of 100.

## 4.7 MODEL CALIBRATION

The model was calibrated first to steady-state (pre-mining) conditions and then to transient (i.e., time dependent) conditions. The steady-state calibration consisted of adjusting the model input data, primarily the recharge and hydraulic conductivity values, until the calculated ground-water elevations and ground-water discharges to streams reasonably replicated the known or assumed conditions prior to any major mining or pumping stresses. The water levels or hydraulic heads calculated in the steady-state calibration were then used as the initial heads for the subsequent transient calibration. During the transient calibration, the values of the model input data (especially the storage and hydraulic conductivity values) were then further





refined until predicted water-level changes reasonably replicated measured water level changes resulting from the hydraulic stresses (e.g., pumping, mine inflows).

## 4.7.1 Steady-State Calibration

For the steady-state calibration of the model, the elevation-dependent long-term average recharge (described in Section 3.5) was applied to all elements at the top of the uppermost layer in the model. The primary criterion for steady-state calibration was the matching of modeled pre-mining water levels to measured values, and matching stream baseflows to measured or estimated values. Since there were no pre-mining measurements of water levels in much of the HSA, the more general criterion for steady-state calibration in much of the HSA was simple that the calculated water table should be below ground surface. The hydraulic properties of the thin uppermost layer were adjusted until these criteria were met. Figure 15 shows a comparison of modeled to limited measured pre-mining water levels in shallow and deep monitoring wells.

It should be noted that the hydraulic conductivity of the thin surface layer and the recharge comprise a non-unique combination to replicate the water table elevations and the baseflows of the various streams and springs. In the conceptual model, the thin uppermost layer represents a near-surface zone of weathered and broken rock whose thickness and hydraulic properties have not been measured and, even if they were, would be highly variable. The assumed hydraulic conductivity is then "coupled" with the assumed recharge to produce reasonable water levels and baseflows. HCI believes that the combination of hydraulic conductivity of the near-surface zone and recharge used in this investigation is quite reasonable.

An estimate of the recharge factor to the deep aquifer system was obtained during calibration of the model by varying the vertical hydraulic conductivity of the Blackhawk Formation layers in the model. Model simulations were run until measured average streamflows in each sub-basin were matched. The resulting vertical hydraulic conductivity of the upper model layers were used in all further modeling to ensure reasonable recharge to the deep ground-

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water system. The steady-state calibration also included adjusting the hydraulic properties of the sandstone units and the faults until a reasonable representation of deep ground-water levels and hydraulic gradients was obtained. The model-calculated pre-mining water levels in the upper Starpoint Formation derived by the steady-state calibration are shown in Figure 16.

The water budget, often alternatively referred to as the water balance or hydrologic budget, for the entire model domain at any instant in time can be described by the relationship:

$$I + R - Et \pm SW - O \pm \Delta S \approx 0 \tag{6}$$

where

I = ground-water inflow,

R = recharge to ground-water system,

SW = net surface-water flow to/from ground-water system

O = ground-water outflow, and

 $\Delta S$  = change in ground-water storage.

The recharge (R) is assumed to be the remainder of precipitation less evapotranspiration and runoff. In the case of steady-state flow,  $\Delta S$  is equal to zero. The values for the various components of the water budget obtained during the average, long-term, pre-mining ("steady-state") calibration of the Skyline model are shown in Table 6.

Table 7 is a comparison of modeled vs. measured and estimated stream baseflows. The volume of simulated ground-water discharge to surface streams cannot easily be calibrated to gaged baseflow of the streams. For example, the model-calculated value for Fish Creek of 6.9 cfs does not compare well with the long-term average measured value of 11.5 cfs until it is recognized that only about half of the Fish Creek drainage is represented in the model. Furthermore, the value for all of Huntington Creek as far as the Left Fork confluence (20.0 cfs) and the value for Left Fork (15.3 cfs) cannot be directly calibrated because reservoir operations make it impossible to gage baseflow in those streams. Based on the size and elevations of the



two large basins and on long-term average October discharge from Electric Lake, the values in Table 7 appear to be reasonable.

The discharge to Mud Creek (12.5 cfs) calculated during steady-state calibration of the model also initially appears to be a poor replication. The baseflow of Mud Creek below Winter Quarters is only 7.3 cfs, but only about 80 percent of the drainage is represented in the model. The source of the large simulated discharge to Mud Creek is the deep aquifer system, discharging at outcrops of the Starpoint Sandstone and faults in lower Eccles Creek (3.4 cfs vs. a gaged 1.8 cfs), Winter Quarters Canyon (4.9 cfs vs. an estimated 1.9 cfs), and Woods and Green Canyons (2.4 cfs, combined, vs. an estimated 1.9 cfs). The model simulates discharge of deep ground water into these drainages as a result of fault-defined no-flow boundaries and the very simplified near-surface occurrences of the Starpoint Sandstone units. In reality, the structure and stratigraphy are much more complicated around Scofield Reservoir; and as discussed in Section 2.5.3, deep ground-water discharge is probably much more diffuse than can be simulated in a model. When the anomalous flows to Woods, Green, Eccles and Winter Quarters Creeks are factored out (Table 7), the remaining modeled discharges to Mud Creek calibrates well to the estimated and gaged baseflows.

## 4.7.2 Transient Calibration

In the transient calibration, the goal was to replicate the existing data on historic water level changes and mine inflows. For this step of the calibration, the average recharge (Section 4.3.3) was again applied to all elements at the top of the uppermost layer in the model. During the calibration process, the hydraulic properties of the various hydrogeologic units, the transmissivity of the various faults, and the connectivity factors for the drain nodes were adjusted until a reasonable representation of ground-water inflows and water levels was obtained.



A comparison of the results of the transient calibration of the model to the measured inflows to the Skyline Mine is shown in Figure 17, and Figure 18 provides a comparison of calibrated to measured water level changes in the various monitoring wells and piezometers. HCI believes this transient calibration reasonably matches the measured and computed groundwater flows and water level changes in the model area.

Table 6 includes the values of the simulated ground-water budget for mining conditions as of April 30, 2003.

The comparison of ground-water discharges to streams calculated during the transient calibration to gaged stream baseflows were similar and have the same limitations as described above under the steady-state calibration.



# 5.0 RESULTS OF MODELING

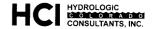
#### 5.1 CURRENT CONDITIONS

Figures 19 and 20 show the model-calculated ground-water levels and drawdowns, respectively, in the upper Starpoint Formation (model layer 13, Figure 12) as of April 2003. The water levels shown in Figure 19 compare most favorably with the potentiometric surface interpreted from measured water level data shown in Figure 4.

The most significant finding of the model simulations is that it is possible to account for essentially 100 percent of the inflow to the Skyline Mine by depletion of storage in the deep ground-water system. In other words, no significant additional sources of water -- either shallow ground water or surface water -- are required to balance the amount of water removed from storage in the deep ground-water system and that has flowed into the Skyline since 1982.

The model indicates that before mining, about 5 cfs (about 2,200 gpm) flowed through the deep aquifer system between the Gooseberry and Connelville Faults from the recharge area southwest of Huntington Reservoir to the discharge area in and around Scofield Reservoir. As described above, fault-defined no-flow boundaries and near-surface and surface exposures of the Starpoint sandstones result in discharge of ground water in Woods Canyon, Eccles Creek, and Winter Quarters Canyon. Mine inflows and the pumping from JC-1 have had only a very small effect on this throughflow, reducing it by approximately 0.5 cfs (225 gpm) as indicated in Table 6 (the difference in the current pre-mining combined discharges to Mud Creek and Fish Creek).

Table 6 also indicates that the calculated impact to Electric Lake, defined as the sum of the difference in recharge to ground water from Electric Lake (pre-mining vs. current) and the difference in ground-water discharge to Upper Huntington Creek and Electric (again, pre-mining vs. current) is 0.2 cfs (90 gpm).



A sensitivity analysis was conducted to evaluate a range of factors that might result in model calculations of greater inflow from Electric Lake into the mine workings. The first part of the sensitivity analysis evaluated the hydraulic conductivity of the Blackhawk Formation. It was found that no reasonable values for the hydraulic conductivity of the Blackhawk Formation could cause any measurable flow of surface water downward into the mine. Using values of hydraulic conductivity much higher than in the model resulted in very poor calibration to the shallow monitoring well data.

The next factor evaluated was the vertical hydraulic conductivity of the Diagonal Fault beneath Electric Lake. Figure 21 shows the effects of incremental increases in the vertical hydraulic conductivity of the upper portion of the Diagonal Fault under the Electric Lake by four orders-of-magnitude from the model-calibrated value of 0.01 ft/day (Table 5). It should be noted that the hydraulic conductivity of the fault could not be increased in any portion of the fault other than between the lake and the mine — an unusual constraint — without causing significant, unmeasured drawdown in the Blackhawk Formation. The results of the sensitivity analysis shown in Figure 21 have to be judged in terms of the "re asonableness" (which is obviously subject to different opinions) of:

- 1) the Diagonal Fault only having enhanced hydraulic conductivity under Electric Lake and
- 2) hydraulic conductivity in a fault within relatively plastic rocks could be as high as those included in the sensitivity analysis.



## 5.2 PREDICTIVE SIMULATIONS

Additional numerical simulations were made to predict the rate at which mine inflows might change over time if left unmitigated. The simulations assumed that

- a) mining would proceed into the Winter Quarters area as projected on currently available mine plans, and
- b) pumping would continue from JC-1 at the current rate of 4,000 gpm.

It was found, however, that the model predicts a slight reduction in the pumping rate of JC-1 to 3,800 gpm after year 2011 when it is predicted that the water level in the well will reach the top elevation of the Panther formation.

Figure 22 summarizes the results of the predictive simulations under these assumptions. The total inflow to the Skyline mine from all sources is predicted to decrease significantly over 10 years to approximately 3,700 gpm including inflow of about 3,200 gpm from the seven major inflows. The predicted decrease is the result of depletion of storage in the deep aquifer system and the associated decrease in head differences between the top of the deep sandstones and the mine. It should also be noted that the predicted inflows are based on the additional assumption that the inflow to the mine would continue to be pumped out into Eccles Creek or, via JC-3, into Huntington Creek. If the inflow were allowed to pool, the resulting increased head in the pool would further decrease the inflow rates.

The predictive simulations also indicate that the mine inflows and continued JC-1 pumping will further decrease the natural ground-water discharges in the Scofield area in the future. The model predicts that such discharges will be about 17.2 cfs (7,700 gpm) in 2013, a decrease of 2.2 cfs (1,000 gpm) relative to the pre-mining rate.



# 6.0 CONCLUSIONS

The Skyline Mine model is a hydrogeologically-based ground-water flow model that is calibrated to existing data and incorporates reasonable hydrologic assumptions. The model has been used to investigate the interactions of surface water, ground water, and mining stresses in the vicinity of Skyline Mine. The primary conclusions of this investigation are:

1) The inflows to the Skyline Mine do not include a significant component of Electric Lake water. This conclusion of the model corroborates three other lines of evidence as summarized in the following table:

Basis of Estimate		Amount (gpm)	Comments	
Ground-water flow model	base case	90 most-reasonable parameters		
	Sensitivity analysis	90-1,600	higher values based on unreasonable input values	
Tritium analyses		1,200	"surface" water, though not necessarily from Electric Lake	
Tracer tests		0	two Electric Lake-specific tests conducted by PacifiCorp	
Temperature		no unique value	origin 600 to 1,000 ft deeper than mine	

- 2) The ground-water flow model also corroborates early monitoring-well records showing that the pre-mining ground-water flow direction beneath the Skyline Mine was primarily to the north-northeast. Ground water in the sandstones exposed at the lower end of Electric Lake flowed both northeast and southeast away from the lake.
- 3) Mining-related stresses have not changed the overall flow directions. However, a localized drawdown cone has developed beneath the level 2 mine workings. Current drawdown exceeds 350 ft at the maximum point.
- 4) The model estimates that mining-related stresses currently cause a decrease in the discharge to Scofield Reservoir and its tributary streams of about 0.5 cfs (220 gpm) relative to the pre-mining discharge. The model predicts that this impact might increase to about 2.2 cfs (1,000 gpm) by 2013 (assuming continued pumping from JC-1, and continued pumping from the Skyline Mine).



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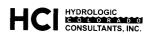
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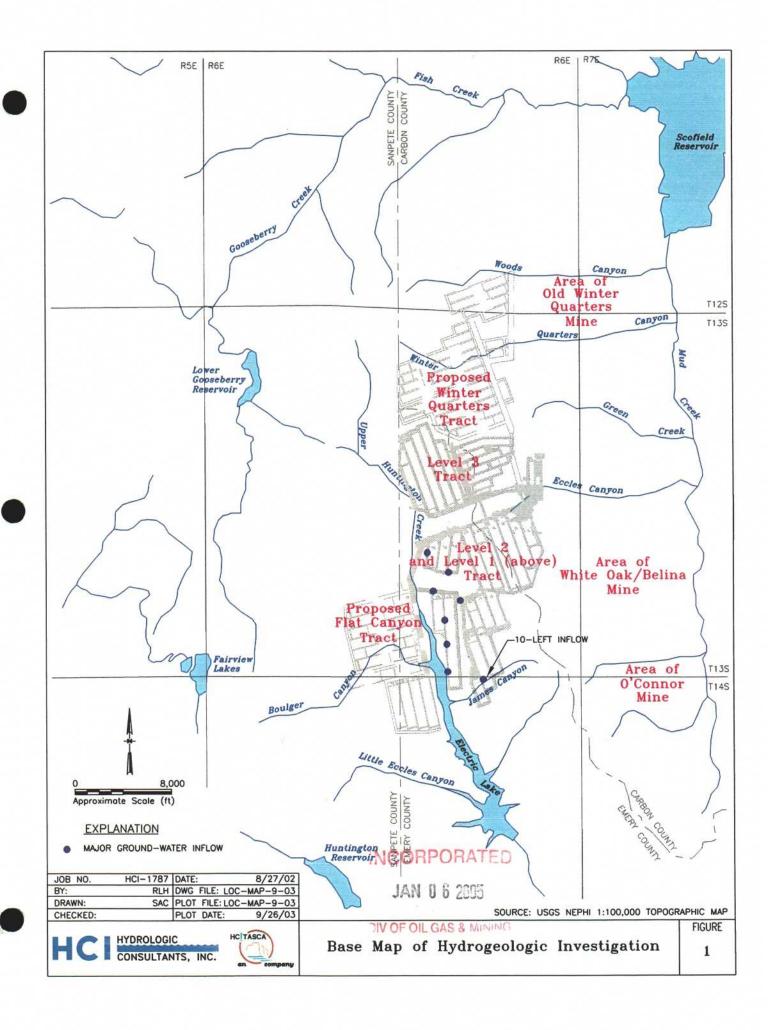
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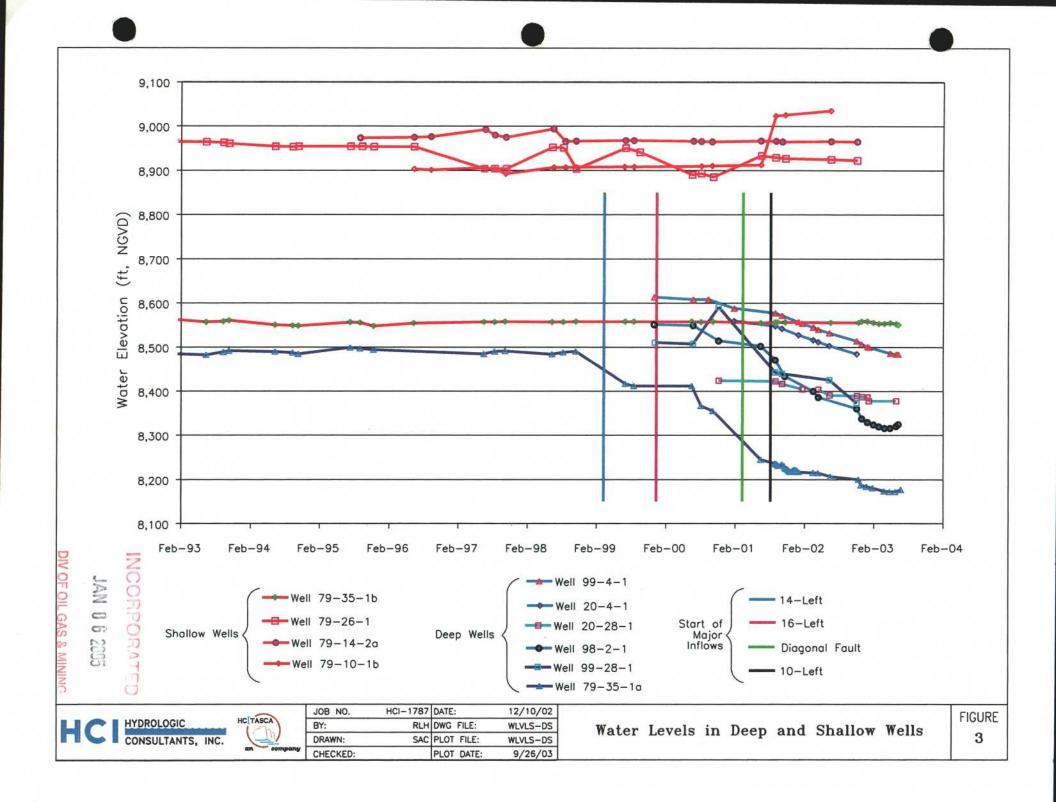


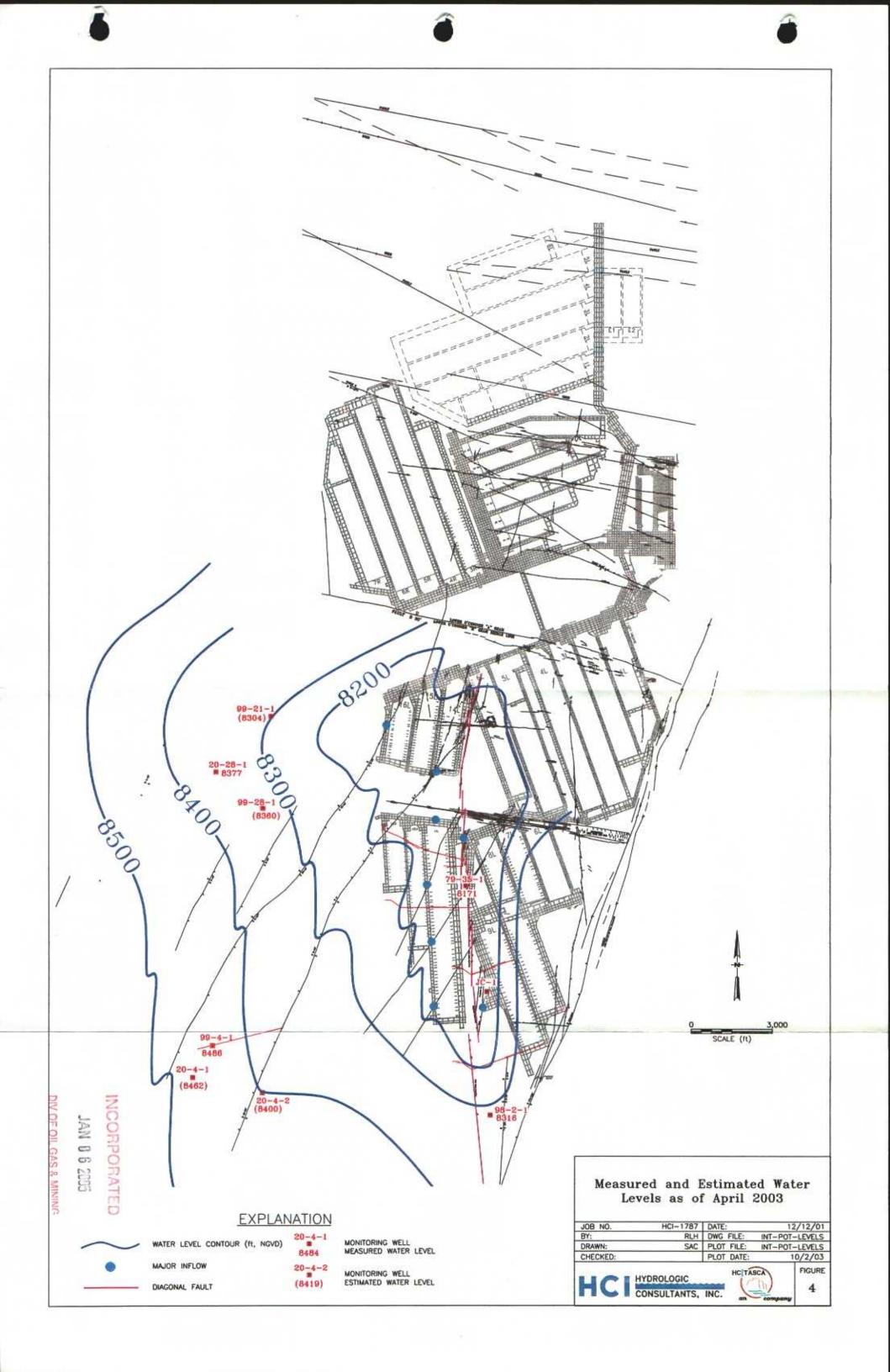
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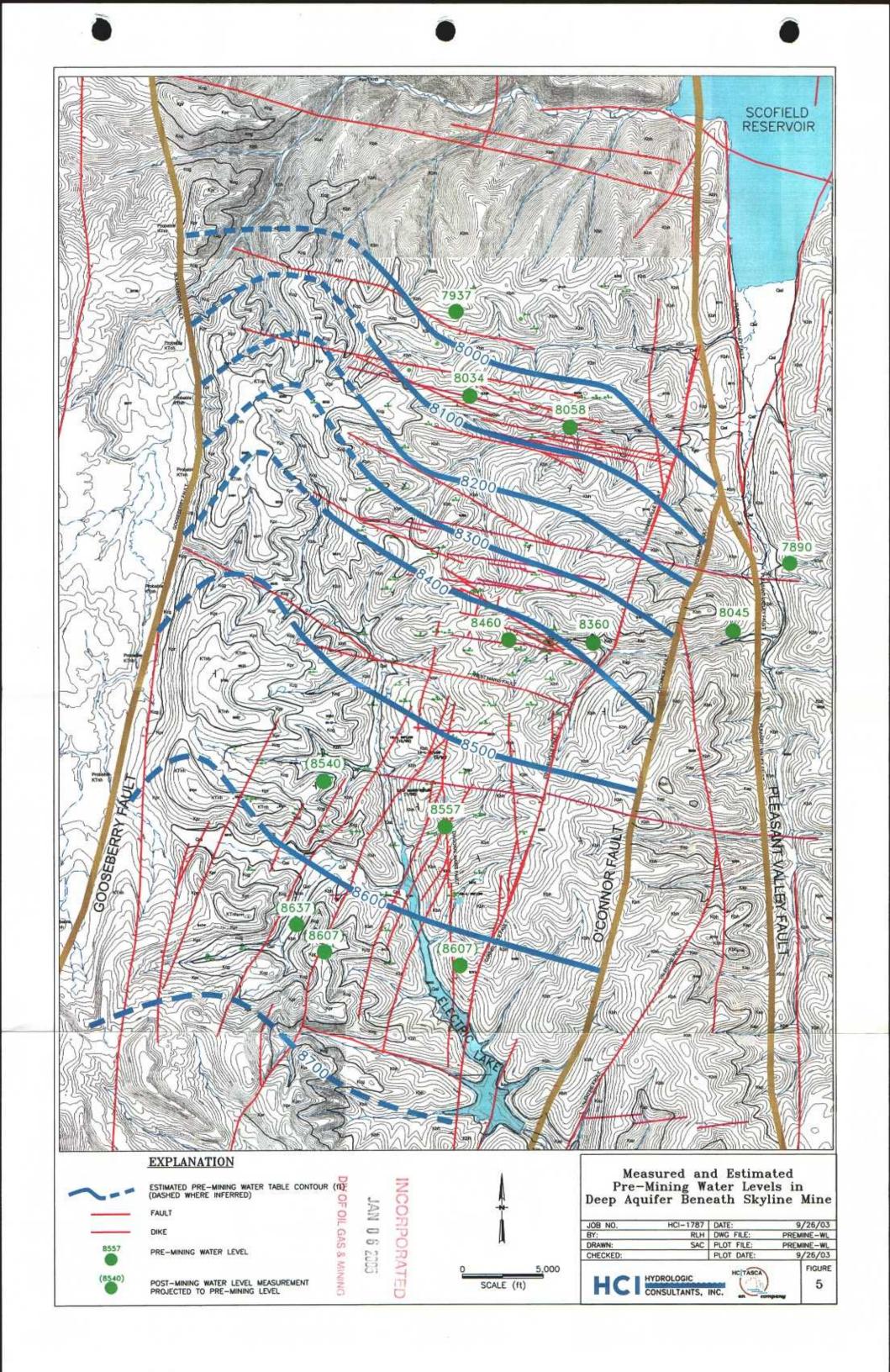
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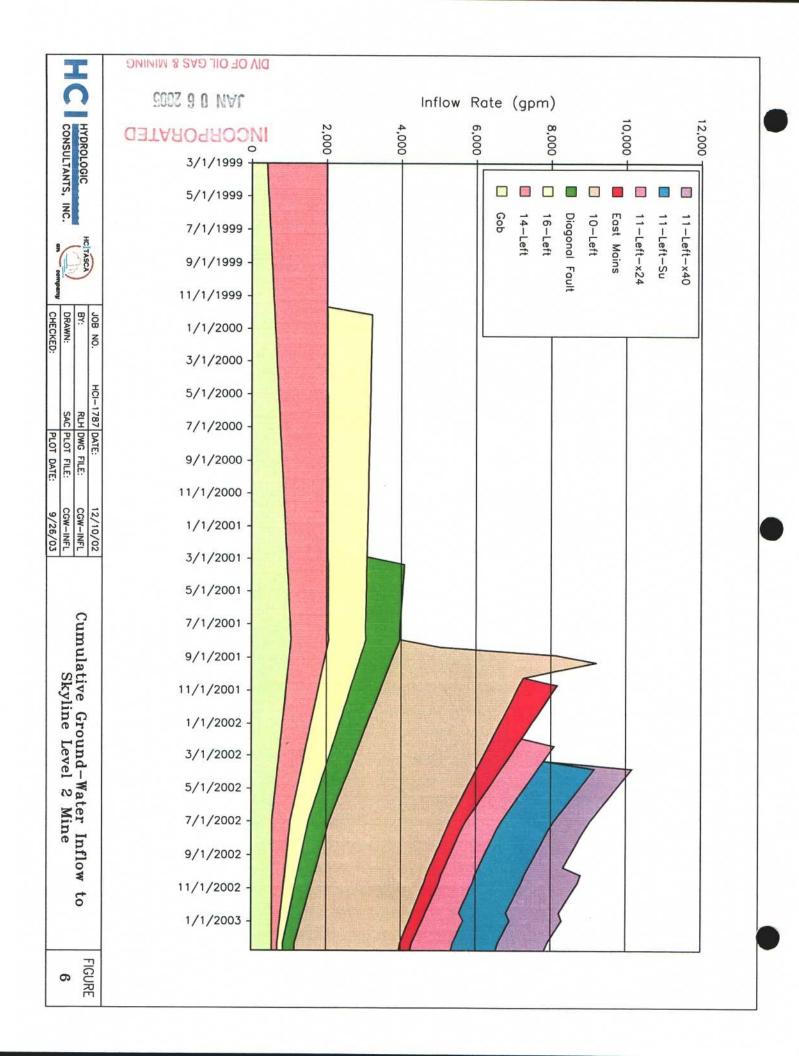
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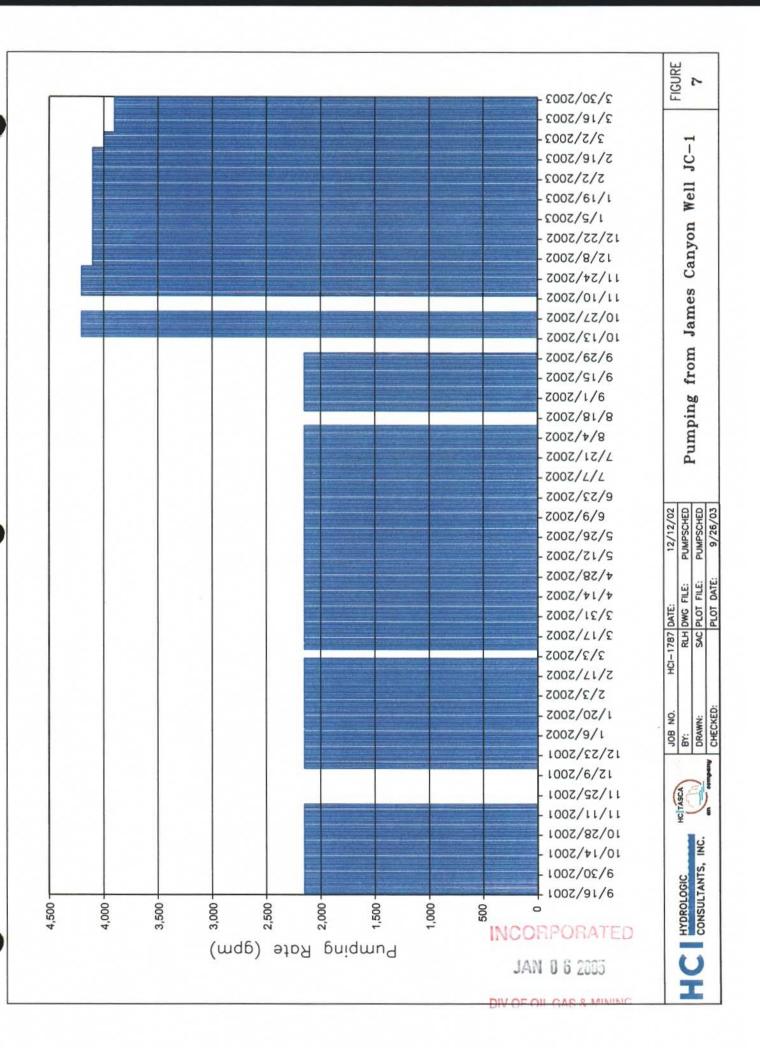


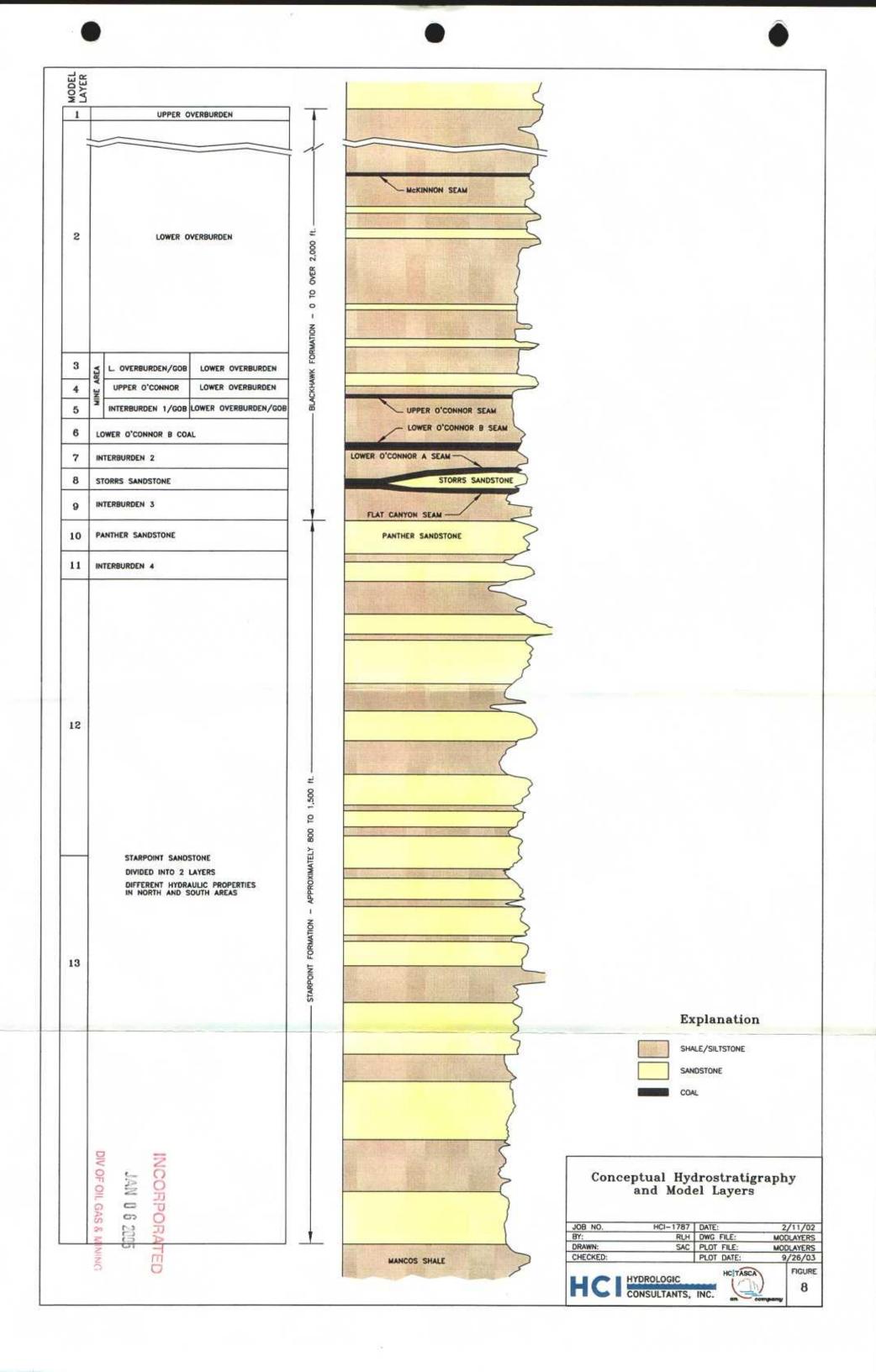


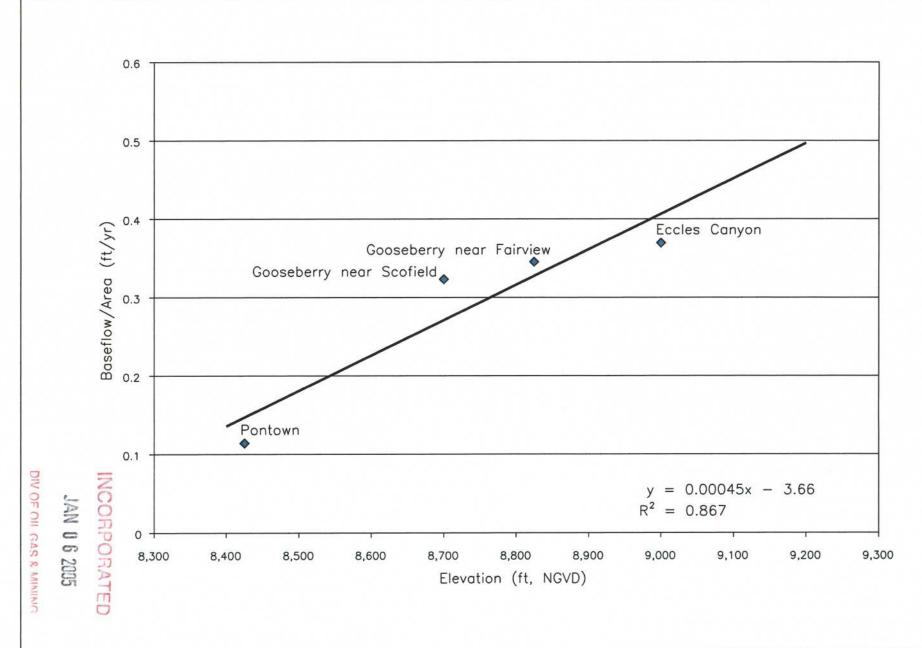












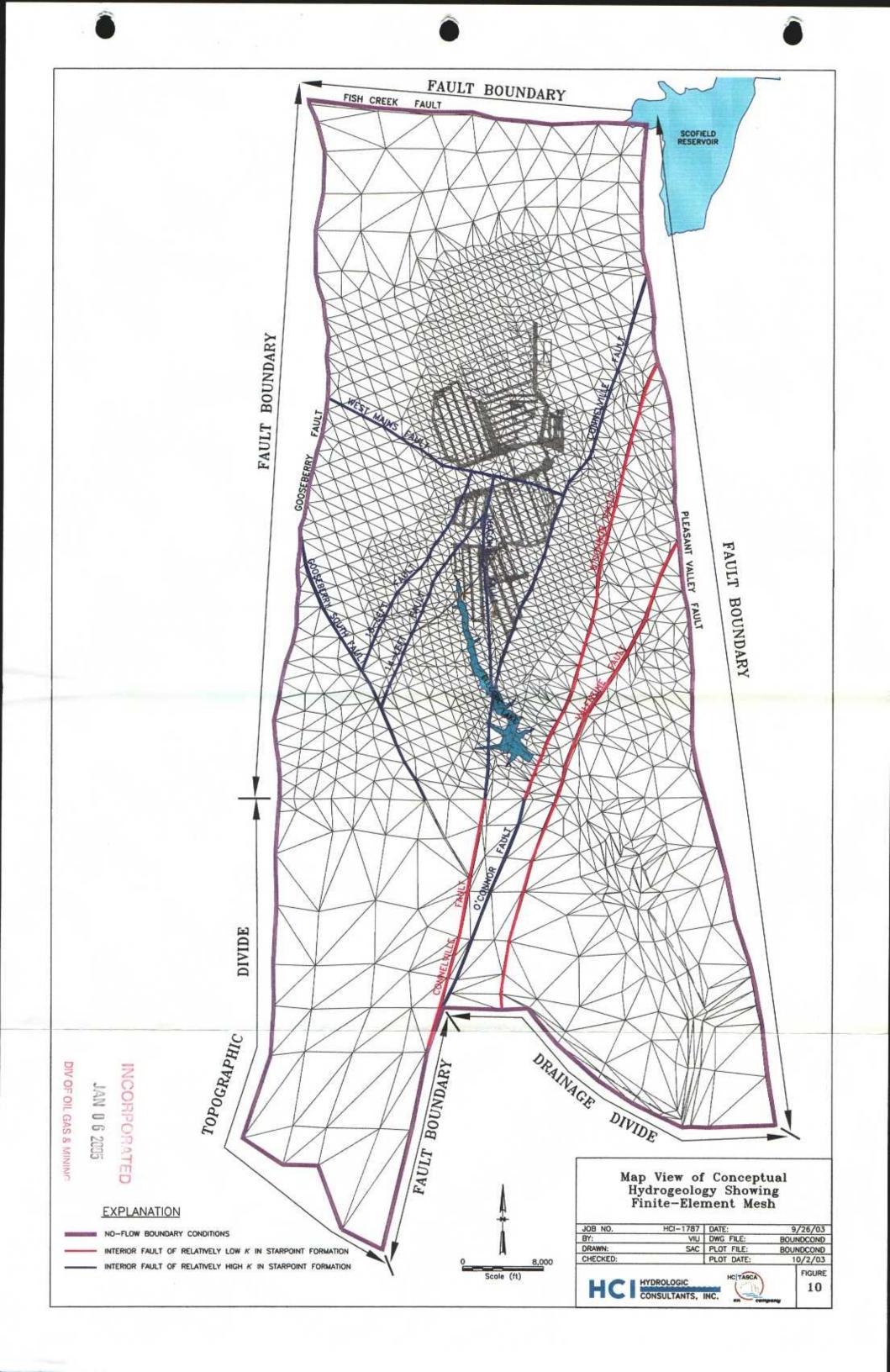


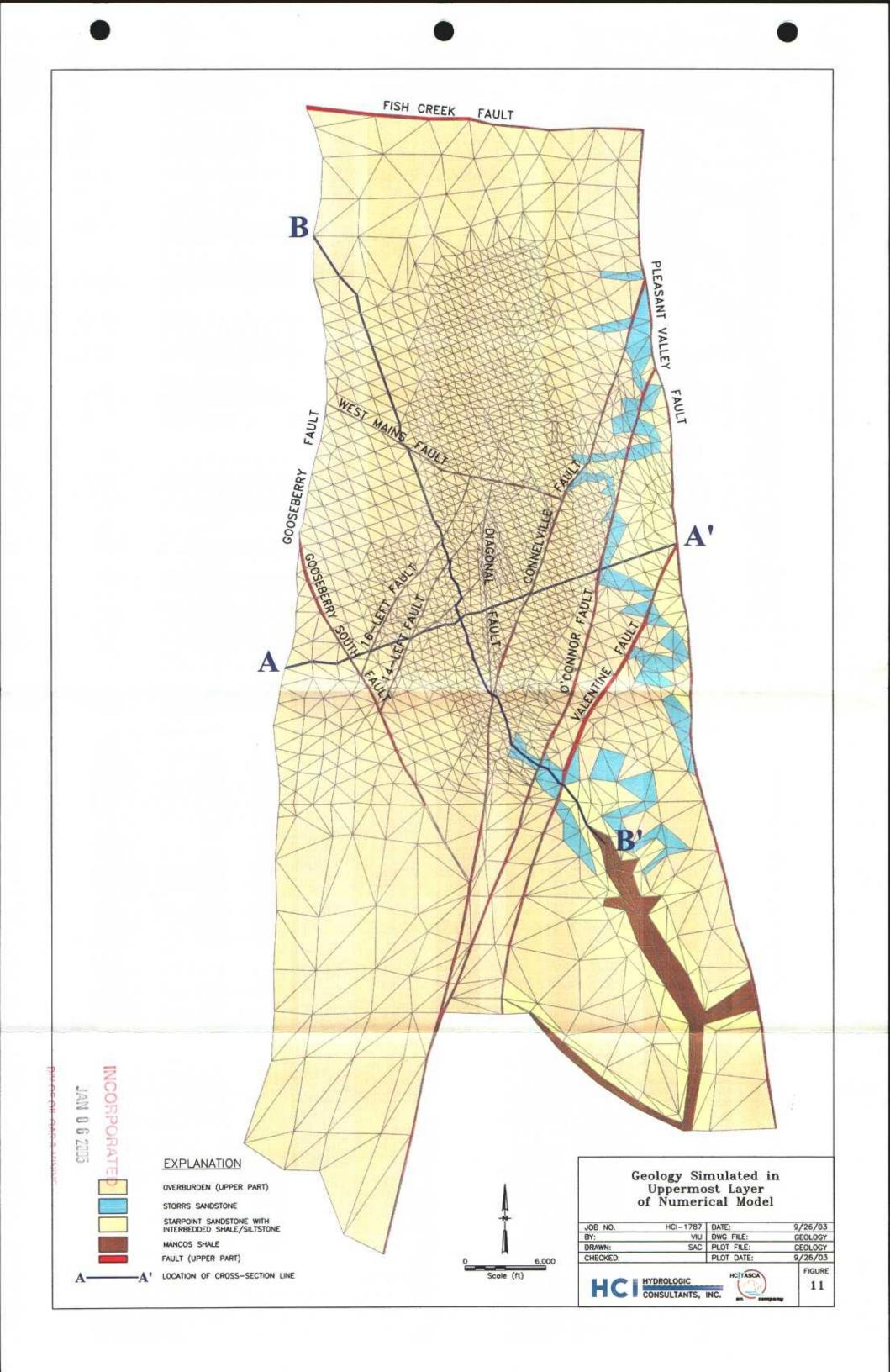


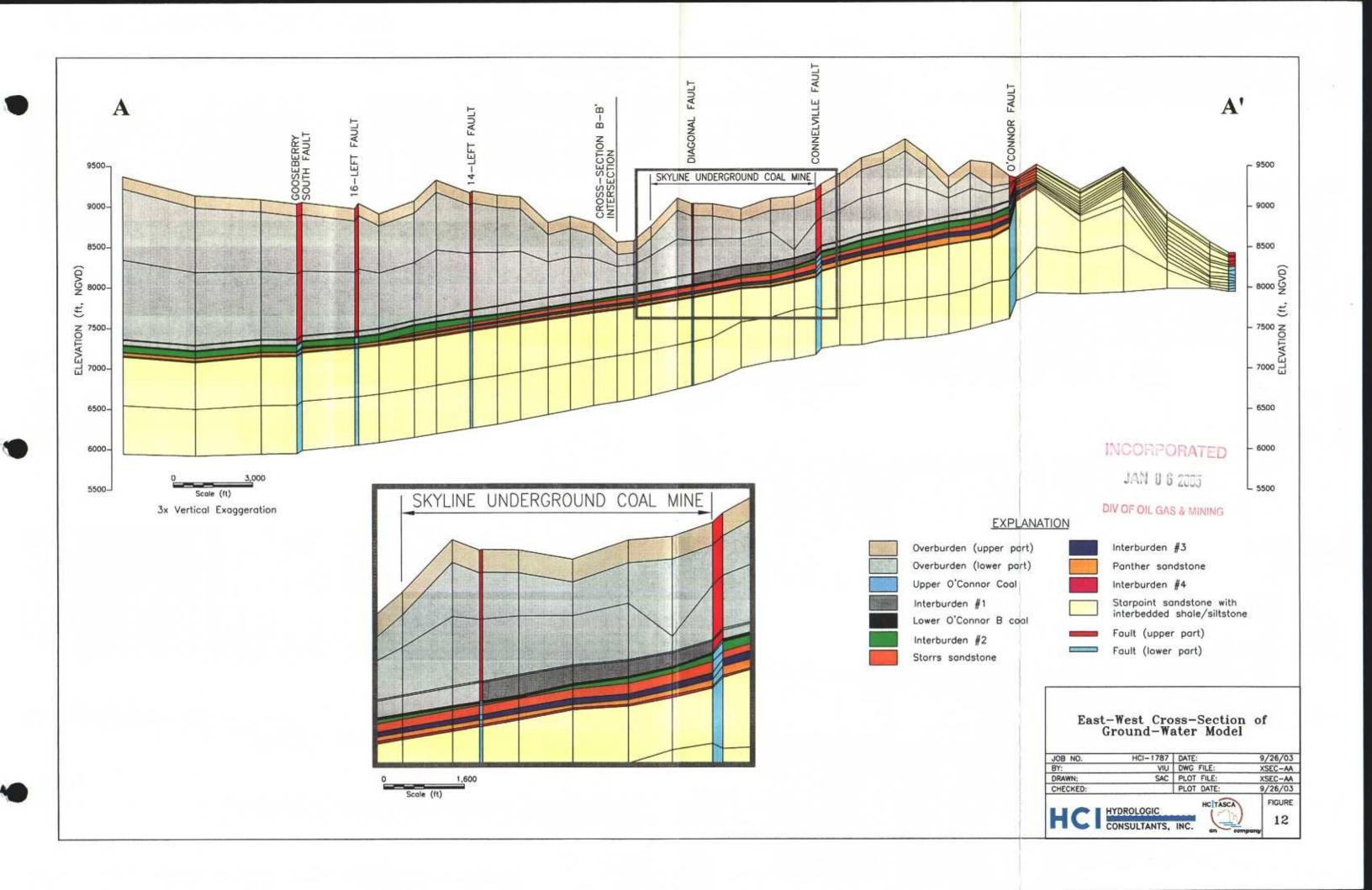
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CHECKED:		PLOT DATE:	9/26/03	

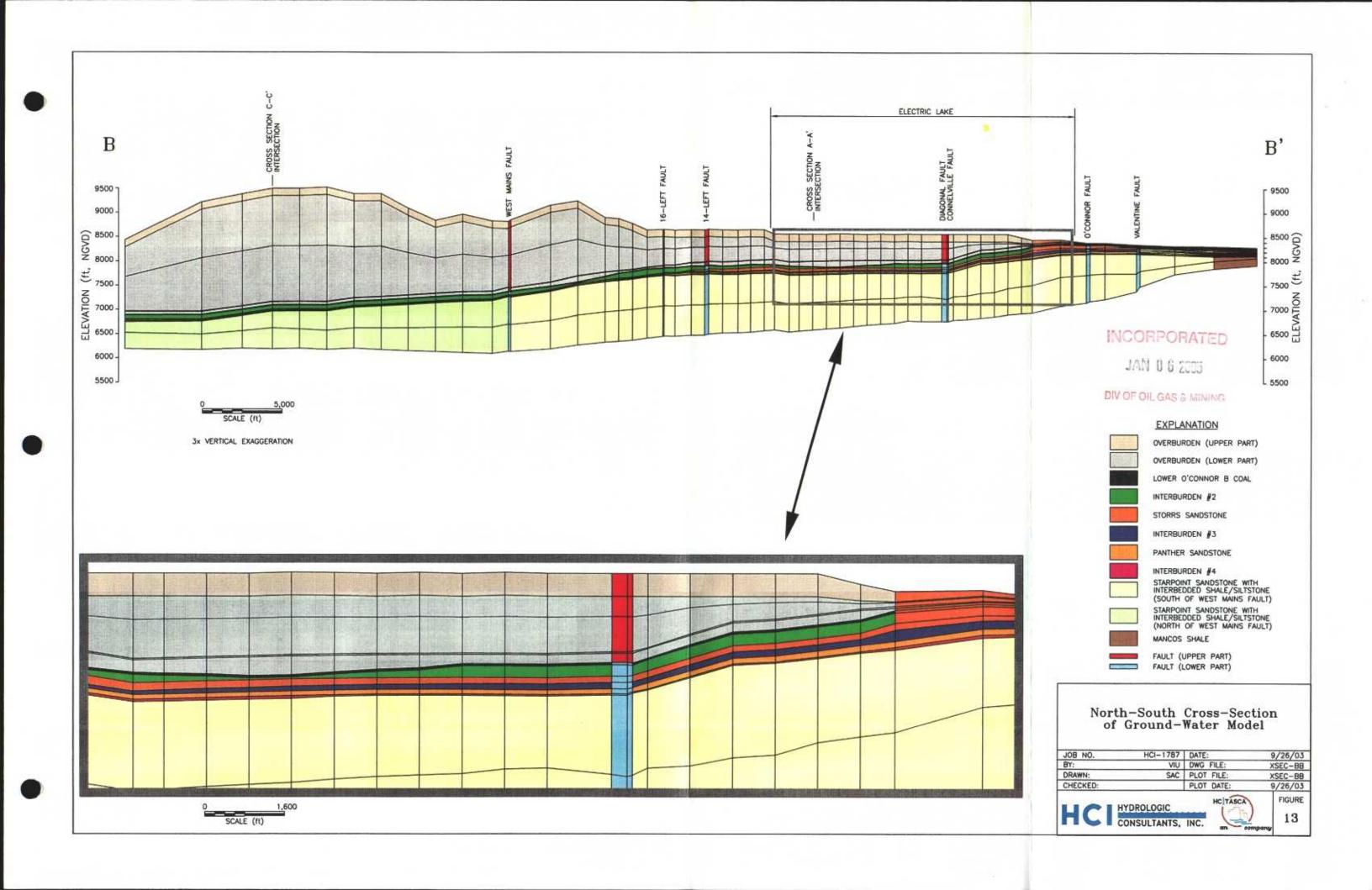
Elevation vs. Recharge in Moderate-Size Stream Basins

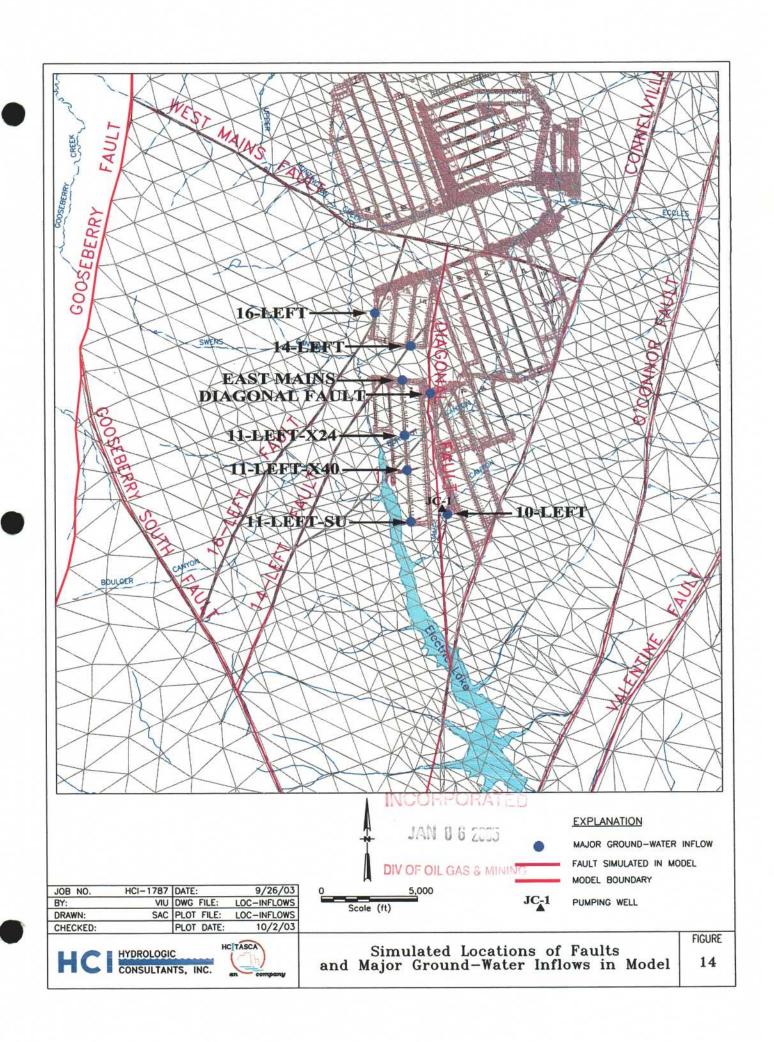
FIGURE 9





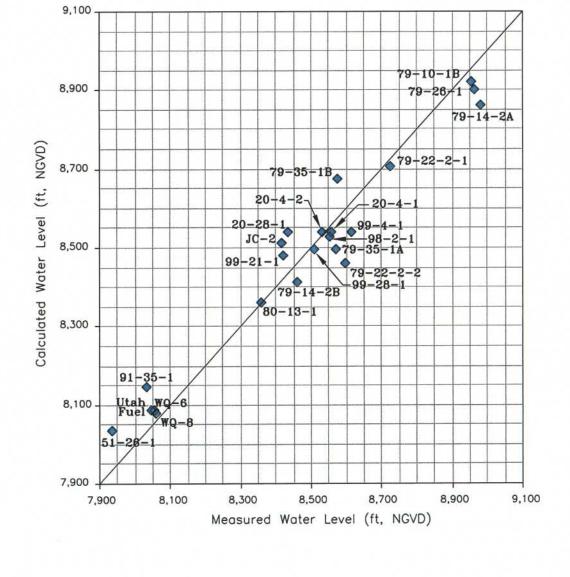






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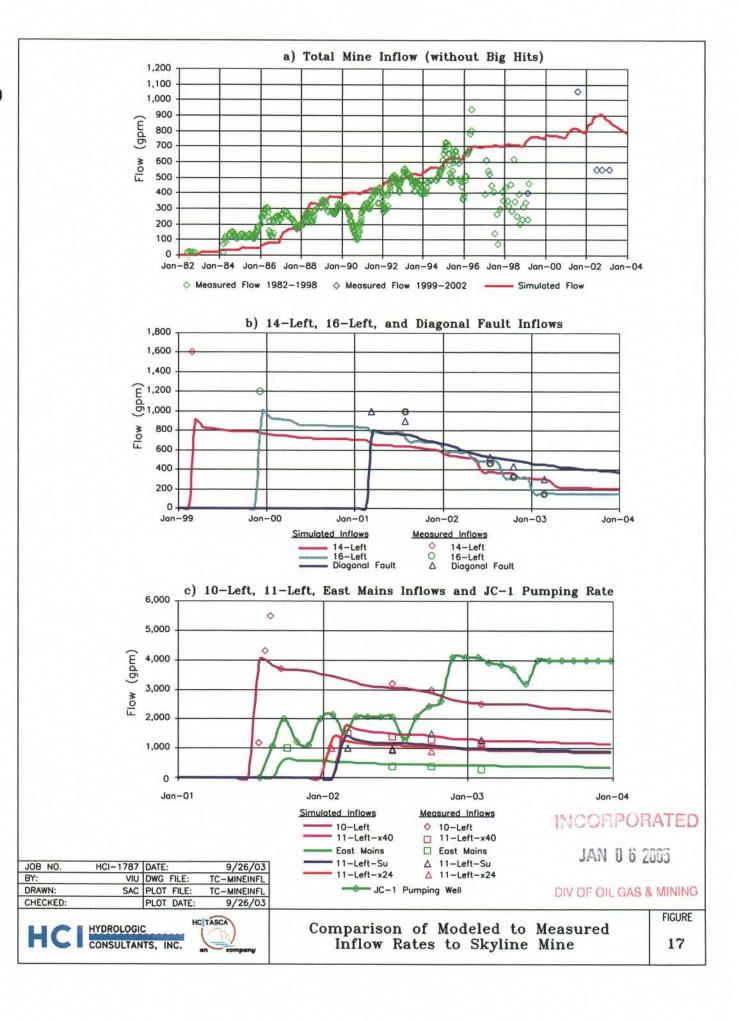


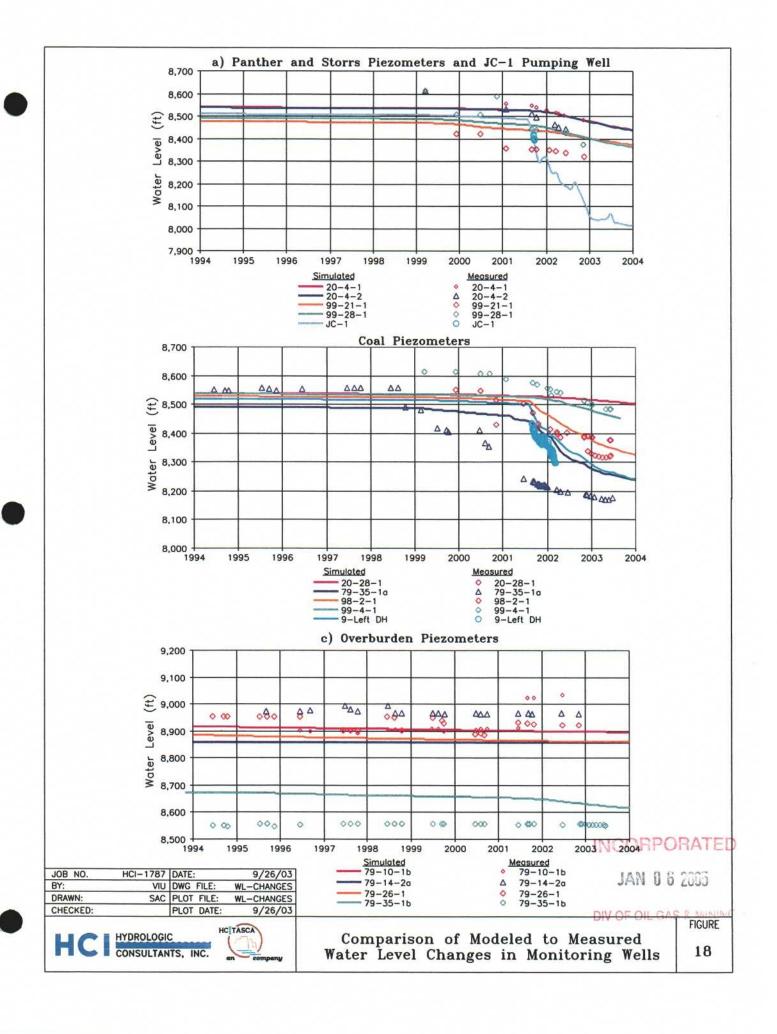


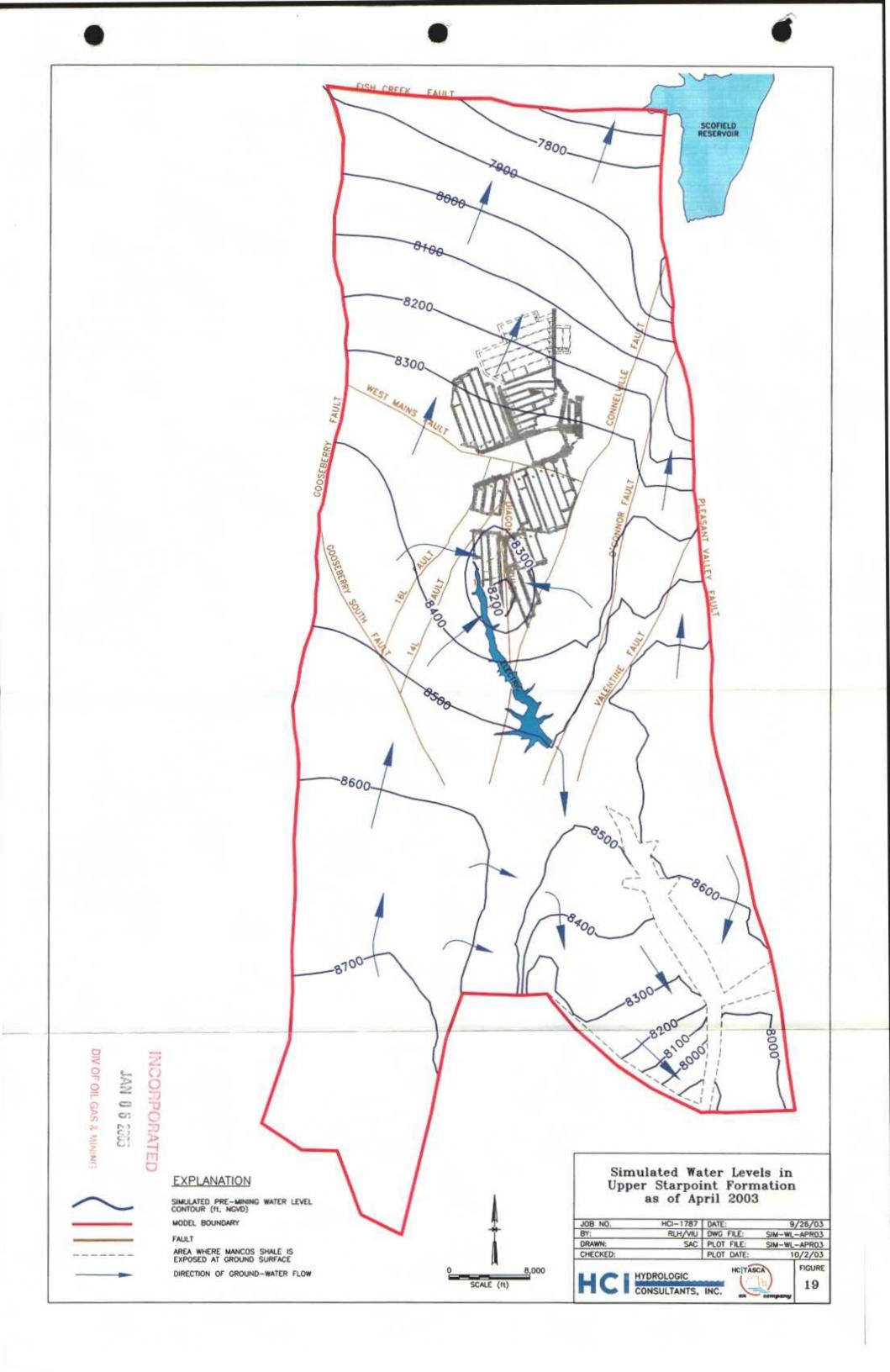
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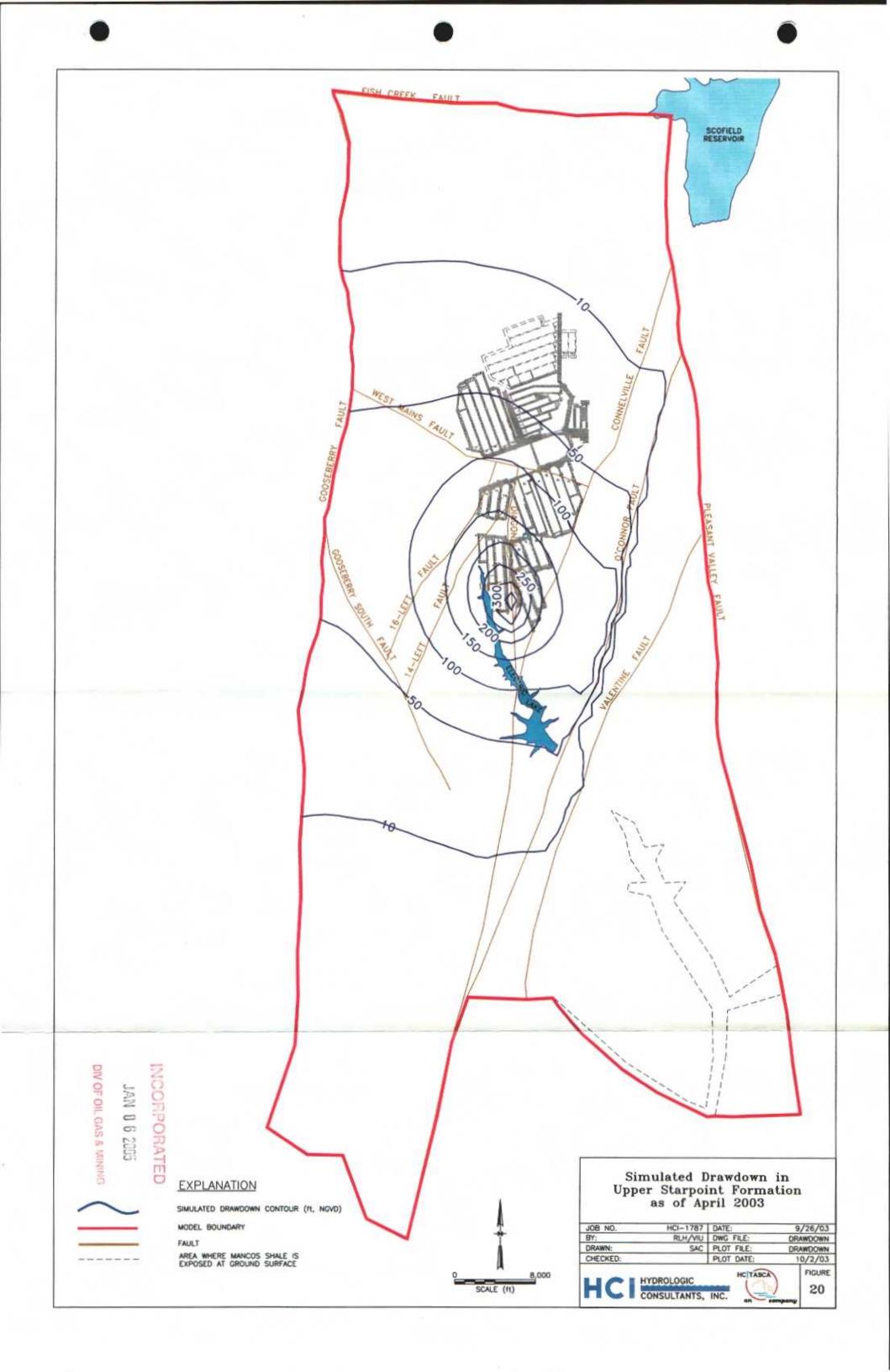
Comparison of Modeled to Measured Pre-Mining Water Levels in Monitoring Wells



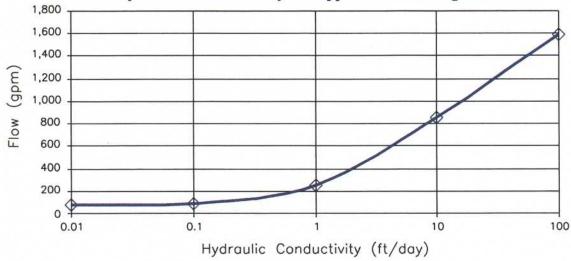


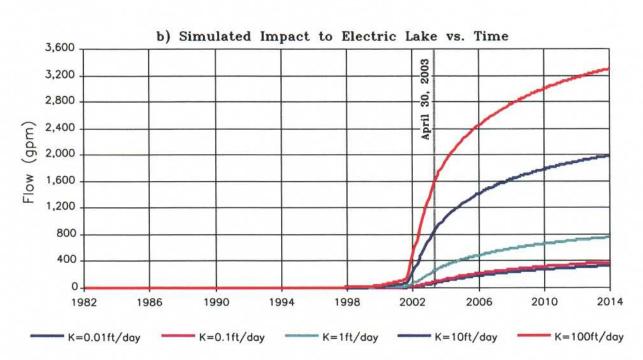






# a) Simulated Impact to Electric Lake as of April 30, 2003 vs. Hydraulic Conductivity of Upper Part of Diagonal Fault





# INCORPORATED

JAN 0 6 2005

JOB NO.	HCI-1787	DATE:	9/26/03
BY:	VIU	DWG FILE:	LAKE-OUTFLOW
DRAWN:	SAC	PLOT FILE:	LAKE-OUTFLOW
CHECKED:		PLOT DATE:	

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Simulated Possible Impact to Electric Lake vs. Hydraulic Conductivity of Upper Part of Diagonal Fault under Lake FIGURE 21

12,000 11,000 10,000 9,000 8,000 7,000 Flow (gpm) 6,000 5,000 4,000 3,000 2,000 1,000 DIV OF OIL GAS & MINING INCORPORATED Jan-98 Jan-00 Jan-02 Jan-04 Jan-06 Jan-08 Jan-10 Jan-12 JAN 0 6 2000 Total Mine Inflow Major Inflows

HCI HYDROLOGIC CONSULTANTS, INC.



JOB NO.	HCI-1787	DATE:	9/26/03
BY:	VIU	DWG FILE:	SIM-INFL
DRAWN:	SAC	PLOT FILE:	SIM-INFL
CHECKED:		PLOT DATE:	9/26/03

Simulated Total Ground-Water Inflow to Mine Through 2013

**FIGURE** 22



TABLE 1
Yield and Baseflows of Gaged Streams in Skyline Mine Area

USGS Station Number and Name	Watershed Area (ft <sup>2</sup> )	Average October Flow (cfs)	Estimated Average Elevation (ft)		Recharge to Shallow Ground Water (ft/yr)
9309800 Gooseberry Creek near Fairview, UT	2.09E+08	2.29	8,825	28.73	0.35
9310000 Gooseberry Creek near Scofield, UT	4.68E+08	4.95	8,700	27.42	0.32
9310550 Pontown (Pondtown) Creek, near Scofield, UT	3.23E+08	1.17	8,425	24.53	0.11
9310600 Eccles Canyon near Scofield, UT	1.53E+08	1.80	9,000	30.57	0.37

#### Note:

1. Recharge to shallow ground water is assumed to be equal to discharge from shallow ground water, or stream baseflow.



TABLE 2

Monitoring Well Information

Wells		Collar Screen Depth (ft < TOC)		Formation	Earliest W:	ater Elevation	Notes
		(ft, NGVD)	(11 < 100)		Date	(ft, NGVD)	
	79-35-1b <sup>(1)</sup>	8,722	180?	Blackhawk	Jul-82	8576	Burnout Canyon
*	79-10-1b	9,383		Blackhawk	Jul-82	8955	Upper Huntington
Shallow	79-22-2-1	9,042		Blackhawk	Aug-83	8727	Kitchen
Sh	79-26-1	9,019		Blackhawk	Jul-83	8964	Upper James Canyon
	79-14-2a	9,052		Blackhawk	Jul-83	8980	Upper Eccles Creek
	79-35-1a <sup>(1)</sup>	8,722	624	LOB	Jul-82	8572	Burnout Canyon
	98-2-1m <sup>(1)</sup>	9,271	1,251	LOB	Dec-99	8551	James Canyon
	79-14-2b	9,052	8,356	LOA	Jun-86	8460	Upper Eccles Creek
	99-28-1	9,351	1,890	Panther	Dec-99	8510	Swens Canyon
	99-21-1	9,348	1,800	Panther	Dec-99	8421	Swens Canyon
	20-28-1 (1)	8,871	1,463	LOB	Nov-00	8432	Swens Canyon
	79-22-2-2	9,042	7,889	LOA/Panther	Oct-83	8596	Cascading water
	99-4-1 <sup>(1)</sup>	8,842	1,302	LOB	Dec-99	8613	Boulger Canyon
C.	20-4-1 (1)	8,874	1,560	Panther	Jan-01	8559	Boulger Canyon
Deep	20-4-2	9,554	2,080	Storrs	Jan-01	8532	Boulger Canyon
	91-26-1	9,217	1,540-1,600	Flat Canyon/Panther	Nov-91	7937	Woods Canyon
	91-35-1	9,224	1,600-1,660	Flat Canyon	Nov-91	8034	Woods/Winter Quarters
	79-10-1a	9,383		LOA?	Jul-82	8922	broken casing?
	80-13-1	8,480	314-1,005	Starpoint	Sep-80	8360	Eccles Creek
	WQ-6	8,167	316-336	LOA/Aberdeen SS	Oct-80	8053	Winter Quarters
	WQ-8	8,121	106-126	LOA/Aberdeen SS	Nov-80	8058	Winter Quarters
	UtahFuel-7	8,080		Starpoint	recent	8045	Lower Eccles Creek
	Waste Rock	8,000		Blackhawk?	recent	7890	Lower Mud Creek
	JC-2	8,802	910-850	Storrs	Sep-01	8418	James Canyon

#### Note:

1. Water levels electronically monitored since Fall 2001.



TABLE 3

Timing and Volume of Ground-Water Inflows to Skyline Mine

Location	Date Inflow Began	Elevation (ft, NGVD)	Initial Inflow (gpm)	March 2003 Inflow (gpm)
14-Left Headgate	Mar-99	8,140	1,600	150
16-Left Headgate	Dec-99	7,985	1,200	150
Diagonal Fault	Mar-01	8,150	1,000	300
10-Left	Aug-01	8,040	6,500	2,800
East Submains	Oct-01	8,135	1,000	300
11-Left-x24	Feb-02	8,040	1,000	1,100
11-Left-x40	Mar-02	8,020	1,000	1,300¹
11-Left-SU	Mar-02	8,000	1,500	1,180
	7,280			

#### Note:

1. The fracture at X-Cut 40 was later exposed from X-Cut 40 to about X-Cut 34 along the longwall face; the inflow increased to a total of about 1,500 gpm.





TABLE 4

Hydraulic Properties of Hydrostratigraphic Units
Simulated in Ground-Water Model

Hydrogeologic Unit			Conductivity day)	Specific Storage (ft <sup>-1</sup> )	Specific Yield
		K <sub>h</sub>	K <sub>h</sub> K <sub>z</sub>		()
Overburden <sup>(1)</sup>	upper <sup>(2)</sup>	1	1		
Overburden	lower	0.001	0.0004		0.05
Upper O'Connor	(UO) coal (3)	1	1	6.0E-06	0.05
Interburden #1 <sup>(4)</sup>	)	0.001	0.0004		
Gob (above UO	and LOB) <sup>(5)</sup>	0.01	0.004	6.0E-05	0.10
Lower O'Connor	r B (LOB) coal	1	1		0.05
Interburden #2		0.001	0.0001	1	0.05
Storrs Sandstone	2	1	1		0.10
Interburden #3		0.001	0.0001	]	0.05
Panther Sandstone		1	1	6.0E-06	0.10
Interburden #4		0.001	0.0001	1	0.05
Starpoint	south area	2	0.2	]	0.01
Sandstone north area		0.5	0.05	]	0.01
Mancos Shale (6)		0.001	0.0001		0.05

#### Notes:

- 1) Includes all stratigraphic units above UO coal or LOB coal in area where UO does not exist.
- 2) Includes first 150 ft of weathered rock below the ground surface.
- 3) Has limited distribution in the model between Diagonal and Connelville faults (in mine area).
- 4) Located in the model below UO only.
- 5) Zone of subsidence-induced increase in hydraulic conductivity is assumed to extend 100 ft (about 8 times thickness of LOB) above coal and to have a hydraulic conductivity 10 times greater than lower part of overburden.
- 6) Located in model in area where exposed at ground surface.





TABLE 5

Hydraulic Properties of Faults Simulated in Ground-Water Model

	Simulated Faults		How Simulated in Model	Hydraulic Conductivity (ft/day)  K <sub>h</sub> K <sub>z</sub>		Specific Storage (ft <sup>1</sup> )	Specific Yield ( )
nt	Gooseberry (main)		not explicitly i	ncluded in model;	1		
Large- Displacement	F: 1 C 1	upper		1	1		
Large- placem	Fish Creek	lower		10	10		
L isp	D14 W-11	upper		0.001	1	1	
Ω	Pleasant Valley	lower		1	1	]	
	Connelville (North)	upper	]	0.001	0.01	]	
	Conneiville (North)	lower		1	1	]	
	Connelville (South)	upper	]	0.001	0.01		0.005
ate-	Connervine (South)	lower		0.001	0.01		
Intermediate- Displacement	O'Connor (North)	upper		0.001	0.01	6 x 10 <sup>-6</sup>	
erm pla	O Connor (North)	lower		0.001	0.01		
Inte	O'Connor (South)	upper		0.001	0.01		
	O Connor (South)	lower	E	11	1		
	Valentine	upper	E	0.001	0.01		
	v archime	lower	]	0.001	0.01		
	Diagonal	upper		0.001	0.01		
	Diagonal	lower <sup>1</sup>		10	10		
	Gooseberry South	upper	]	0.001	0.01		
	Gooseberry South	lower	]	1	1		
	14-Left	upper		0.001	0.01		
ant	14-1.611	lower	]	1	1		
II-	16-Left	upper		0.001	0.01		
Small- placem	10-Len	lower	]	1	1	_]	
Small- Displacement	West Mains	upper	_[	0.001	0.01		
		lower		1	1		
	10-Left		_				
	11-Left-a						
	11-Left-b		F				
	11-Left-c		_				
	East Main		<u>                                     </u>				

#### Notes:

- 1)  $K_h = K_z = 100$  ft/day within lower part of Diagonal Fault near pumping well JC-1
- 2) Upper = above LOB, Lower = below top of LOB
- 3) E = explicitly represented by elements with assigned hydraulic properties
- 4) F = simulated with FAULT routine of MINEDW



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TABLE 6
Simulated Ground-Water Budgets for Pre-Mining and Current Mining Conditions

Pre-Mining Conditions						
Inflow	(cfs)	Outflow	(cfs)			
Recharge from Precipitation	54.6	GW Boundary Outflow	0			
GW Boundary Inflow	0	GW Discharge to SW				
Recharge to GW from Electric Lake	0.1	a) Mud Creek	12.5			
GW Storage	0	b) Fish Creek	6.9			
		c) Upper Huntington Creek/Electric Lake	10.6			
		d) Huntington Creek below Electric Lake	9.5			
		e) Left Fork	15.3			
Total	54.7	Total	54.7			
Current Mining Conditions (as of April 30, 2003)						
Inflow	(cfs)	Outfow	(cfs)			
Recharge from Precipitation	54.6	GW Boundary Outflow	0			
GW Boundary Inflow	0	GW Discharge to SW				
Recharge to GW from Electric Lake	0.2	a) Mud Creek	12.1			
GW Storage	25.0	b) Fish Creek	6.8			
		c) Upper Huntington Creek/Electric Lake	10.5			
		d) Huntington Creek below Electric Lake	9.4			
		e) Left Fork	15.2			
		Subtotal	54.0			
		Pumping from JC-1	8.6			
		Mine Inflow	17.2			
Total	79.8	Total	79.8			
Calculated impact to Electric Lake = diff Electric Lake + difference in GW dischar		_	0.2			



TABLE 7

Gaged and Estimated Stream Baseflows vs. Modeled Discharge to Streams

Stream Gage Location	Mean Elevation <sup>1</sup> of Total Drainage (ft, NGVD)	Approximate Area Modeled (ac)	· · · · · · · · · · · · · · · · · · ·	Estimated Shallow Recharge <sup>2</sup> to Modeled Drainage (cfs)	Simulated Discharge to Drainage Including Springs (cfs)
Fish Creek above Reservoir	8,500	27,712	11.5	6.6	6.9
Boardinghouse Creek at mouth	9,200	1,300	1.2		1.7
Eccles Canyon near Scofield, UT	9,000	3,520	1.8		3.4
Winter Quarters Canyon	8,900	4,000		1.9	4.9
Woods Canyon	8,800	3,100		1.3	1.6
Green Canyon	8,800	1,300		0.6	0.8
Mud Creek below Winter Quarters	8,400	18,624	7.3		12.5
Mud Creek excluding Eccles, Green, Woods, and Winter Quarters	9,000	3,900		2.1	1.8
Huntington above Dam			13.0 <sup>3</sup>		10.6
Huntington below Dam, above Left Fork	9,100	10,240		6.3	9.4
Total Huntington Drainage				19.3	20.1
Left Fork	9,200	26,000		17.5	15.3

#### Notes:

- 1. Average elevation of drainages estimated from USGS topographic maps.
- 2. Baseflow estimated from recharge (ft/year) based on: R = 0.00045z 3.66
- 3. Average October-January discharge from dam, 1971 to 2002
- 4. Above Left Fork

# **APPENDIX K**

HCI
SUPPLEMENTAL REPORT
GROUND-WATER FLOW MODELING
OF
SKYLINE MINE AND SURROUNDING AREA,
CARBON, SANPETE, AND EMERY COUNTIES

June 18, 2004

June 1, 2004 HCI-1787

Mr. Chris Hansen Canyon Fuel Company, LLC HC 35 Box 380 Helper, UT 84526

**SUBJECT**: Transmittal of Supplemental Modeling Report

Dear Mr. Hansen:

This letter accompanies a pdf-format copy of a report on supplemental modeling of ground-water flow in and around the Skyline Mine. The modeling was performed and the report prepared by Hydrologic Consultants, Inc. of Colorado (HCI) at the request of Canyon Fuel Company.

The report specifically addresses eight comments and recommendations (deficiencies) submitted by Utah Division of Oil Gas and Mining (DOGM, 2004) pertaining to earlier Skyline groundwater flow modeling (HCI, 2003). Most of the deficiencies and recommendations are addressed in the accompanying report. Those items that were not fully addressed as requested include:

- 1. Item #3 requested a figure representing each layer in the model. HCI prepared 5 such figures, however, several other layers were not represented in separate figures because those layers are redundant (several identical layers, for numerical reasons, representing identical geology).
- 2. Item #5 requests extension of cross sections to show the geology east and west of major faults. However, the cross sections in question are of the model grid, and the faults coincide with the model boundaries. Therefore, no extension is possible there is no model beyond the model boundary. A geological cross section from Cris Kravits' report would better satisfy DOGM's request.

All other items were addressed in full. Please give me a call if you have questions regarding the accompanying report.

Sincerely,

HYDROLOGIC CONSULTANTS, INC. OF COLORADO

Roger L. Howell Project Manager

**References:** 

- Hydrologic Consultants Inc., 2003, Findings of ground-water flow modeling of Skyline Mine and surrounding area, Carbon, Sanpete, and Emery Counties, Utah: report prepared for Manning, Curtis, Bradshaw & Bednar LLC, September.
- Utah Division of Oil, Gas, and Mining, 2004, Findings for HCl ground-water model report in PHC, Canyon Fuel Company, LLC, Skyline Mine, C/007/0005 #1871: Letter to Dan Meadors, April 23.

### SUPPLEMENTAL REPORT

# GROUND-WATER FLOW MODELING OF SKYLINE MINE AND SURROUNDING AREA, CARBON, SANPETE, AND EMERY COUNTIES, UTAH

#### Prepared by

Hydrologic Consultants, Inc. of Colorado an HCItasca Company

for

Manning, Curtis, Bradshaw and Bednar LLC Salt Lake City, Utah

**HCI-1787** 

**June 2004** 

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#### 1.0 INTRODUCTION

This report supplements an earlier report submitted by Hydrologic Consultants, Inc of Colorado (HCI) entitled *Findings of ground-water flow modeling of Skyline Mine and surrounding area, Carbon, Sanpete, and Emery Counties, Utah* (HCI, 2003). The earlier report describes the findings of a three-dimensional ground-water flow model (the 2003 Model) that was developed to evaluate the relationship between ground water and surface water in the vicinity of the Skyline Mine. The current report was written with the assumption that the reader has ready access to HCI (2003).

Skyline Mine, operated by Canyon Fuel Company (CFC), is a longwall coal mine located in the northern Wasatch Plateau of central Utah. The mine began operations in the early 1980s. Large, persistent ground-water inflows have been encountered in the Skyline Mine beginning in March 1999. The total inflow rate to the mine from 8 major inflows reached a maximum of more than 10,000 gpm in April 2002, but had declined to less than 8,000 gpm at the time of the April 2003 modeling, and to less than 6,600 gpm as of April 2004. The operators of Electric Lake, which is located on surface west of the mine workings, have questioned whether water flowing into the Skyline Mine is coming from the reservoir. Together with water chemistry, temperature, and inflow-decay data, results of the 2003 Model suggest that the vast majority of water flowing into Skyline Mine workings comes from a deep ground-water source.

#### 1.1 PURPOSE OF SUPPLEMENTAL REPORT

Although the primary purpose of the 2003 Model was to investigate the origins of ground-water inflows into the Skyline Mine, the model was also used to make preliminary predictions of impacts to surface waters. Those predictions were incorporated into Skyline Mine's PHC submittal for the Winter Quarters development. The Utah Division of Oil, Gas, and Mining (DOGM) reviewed the 2003 Model report, and in late April 2004 requested a number of clarifications, verifications, and additional predictive simulations. The current report is intended to clarify some aspects of conceptualization and construction of the model, and verify the

calibration of the 2003 Model using more recent data. However, as will be shown below, significantly changed mining conditions (since calibration of the 2003 Model) require that the model be modified somewhat in order to make requested predictive simulations.

#### 1.2 HYDROLOGY OF SKYLINE MINE AND VICINITY

#### 1.2.1 Mine Inflows

Throughout the development of Levels 1 and 3 of the Skyline Mine (see Figure 1), mining encountered small, short-lived ground-water inflows, typical of underground coal mines in the western U.S. Beginning in 1999, mining on Level 2 encountered a number of large, persistent ground-water inflows related to a set of north- to northeast-trending normal faults of relatively small displacement. Initial discharges at individual locations might have been as large as 6,500 gpm, although discharges of about 1,000 gpm were more typical. The total mine inflow, which reached a peak of about 10,500 gpm in March 2002, decreased to about 7,500 gpm by March 2003, and to about 6,600 gpm by April 2004 (See Figure 6 in HCI, 2003). Figure 2 shows the locations of the major inflows within the Level 2 mine workings.

Mitigation efforts have had only a minor effect on decreasing the inflow rates in the mine. As described in HCI (2002), pumping well JC-1 was completed into the Storrs sandstone beneath the 10-Left inflow in October 2001. Pumping well JC-3 was completed into the flooded mine workings in July 2003. Figure 3 shows the pumping rates of both wells.

Mining has since been completed in most of Level 2, and beginning in October 2002, ground water was allowed to flood portions of the 8-Left and 9-Left longwall panels up to seals placed at an elevation of 8,110 ft NGVD. The mine again is allowing the pool level to rise, and the higher water levels are effecting the mine hydrology.

#### 1.2.2 Hydrogeology

The hydrostratigraphy of the study area is described in detail in HCI (2003). Rock units are dominated by approximately 1,500 ft of Starpoint Formation sandstones and siltstones overlain by an equivalent thickness of shales and siltstones of the Blackhawk Formation. The Skyline Mine extracts coals at the boundary between these two major units.

Faults with large vertical displacement (the Pleasant Valley, Gooseberry, Fish Creek Graben, and Valentine Faults, and portions of the O'Connor Fault) impede horizontal ground-water flow, whereas numerous north/south-trending structures of small displacement, including portions of the Connelville Fault, locally transmit water.

#### 1.2.3 Ground Water and Surface Water

Ground-water levels in monitoring wells indicate that there are two continuous, but poorly connected ground-water systems in the vicinity of the Skyline Mine: a relatively shallow ground-water system in the Blackhawk Formation, and a deep aquifer system comprised of the Starpoint Sandstones and coals at the boundary between the Starpoint and Blackhawk Formations. Inflows to the mine and ground-water pumping since 1999 have resulted in drawdown of as much as 400 ft over a broad area in the deep aquifer, but they have not affected ground-water levels in the shallow ground-water system (Figure 4).

Pre-mining water-level data indicate that the potentiometric surface of the deep aquifer in the area of the mine had a regional gradient from south-southwest to north-northeast in the range of 0.03 to 0.009 ft/ft (Figure 5 in HCI, 2003). Most of the recharge to the deep aquifer probably occurs in the high country to the south of Huntington and Cleveland Reservoirs. Ground-water discharge is believed to occur in the vicinity of Scofield Reservoir, although direct evidence of the discharge has not been observed.

#### 2.0 2003 SKYLINE GROUND-WATER FLOW MODEL

The stated goals of the 2003 Model investigation were to develop a hydrogeologically-based numerical ground-water flow model that could:

- 1) describe the ground-water system in the vicinity of the Skyline Mine,
- 2) evaluate significantly different explanations of the source of ground water flowing into the mine.
- 3) be used as a management tool for both the ground-water and surface-water resources of the region, and

#### 2.1 CONCEPTUAL MODEL

HCI (2003) describes in detail the essential components of the conceptual model on which the 2003 numerical ground-water flow model was based. The conceptual model includes eleven geologic units, shown in the hydrostratigraphic column in Figure 8 of HCI (2003). The Mancos shale is implied as the basement to the ground-water flow system with a very low hydraulic conductivity.

The conceptual model incorporates recharge to the ground-water system, including shallow-circulating ground water, which re-emerges in the surface-water system, and a much smaller component of deeply circulating ground water; perennial streams and reservoirs and their interaction with the regional ground-water system; ground-water pumping (including mine inflows); and mining and its hydrologically-significant consequences. Hydraulic conductivities of the hydrostratigraphic units and interior faults are shown in Tables 4 and 5 in HCI (2003).

The boundaries of the Skyline model (2003 Model) were selected to coincide with natural hydrologic boundaries, in order to limit the amount of ground-water and surface-water flow that naturally enter and exit the hydrologic study area (HSA). The eastern, western, and northern boundaries are defined by faults of major offset (Figure 5). The southwestern model boundary is defined by a surface-water divide, and the southeastern model boundary follows the channel of

Left Fork where Mancos shale (with very low hydraulic conductivity) is exposed in the creek bed. All of these boundaries are assumed to be no-flow boundaries (i.e., there is no lateral inflow or outflow across them).

#### 2.2 NUMERICAL GROUND-WATER FLOW MODEL

The 2003 Model utilizes the numerical code *MINEDW*, which solves three-dimensional ground-water flow problems with an unconfined, or phreatic, surface using the finite element method (HCI, 1993). The model domain encompasses approximately 140 mi<sup>2</sup>, and the finite-element grid contains 32,172 nodes and 58,188 elements within 13 layers.

The finite-element grid was discretized to incorporate the key hydrogeologic features of the HSA including the sandstone outcrops near the eastern boundary of the model, the location and orientation of the faults, and various surface-water bodies. Representation of the geology and active faults in key layers of the model such as Overburden, LOB coal seem, Storrs, Panther, and Starpoint Formations are shown in Figures 5 through 9, as requested by DOGM (2004). The 13 model layers are shown in cross section in Figures 10 through 12. No changes to the grid were required for the supplemental modeling described in this report.

HCI (2003) describes in detail the methods used to simulate model boundaries, hydrologic features (surface water, hydrostratigraphy, transmissive faults, recharge), and mine excavation, and stresses (major mine inflows, pumping).

DOGM (2004) requested two other specific clarifications of the 2003 model. Figure 13 shows the comparison between modeled and measured pre-mining water levels in monitoring wells, color-coded according to the formation in which the monitoring well is screened. The second requested clarification is of the method used to simulate pumping well JC-1. That method is described below.

#### 2.2.1 Simulation of Pumping Well

Pumping from well JC-1 is simulated explicitly in the model by a pumping node located on the Diagonal Fault in the Panther Sandstone layer. It should be noted that JC-1 was actually completed into the Storrs Sandstone within or immediately adjacent to the Diagonal Fault. In the model, the very large hydraulic conductivity in the fault zone puts the Storrs and Panther sandstones in direct hydraulic connection. Therefore, the pumping node has been assigned to the lower Panther Sandstone interval.

During predictive runs, when the calculated water level reaches an elevation of 15 ft above the top of the Panther within the simulated well, the pumping node is converted to a <u>drain</u> node with specified head elevation. The drain node, using a large leakance factor, fixes the water level in the well at the specified elevation, thus simulating a variable pumping rate dependent on changes in the water level within the formation. This is done in order to prevent simulation of over-pumping by the well at low water levels. (Some versions of *MODFLOW* will automatically guard against this by reducing the pumping rate proportionally to residual transmissivity of the saturated zone.)

#### 2.2.2 Summary of Findings of the 2003 Model

Results of simulations using the 2003 Model indicate that all of the water that has flowed into the Skyline Mine can be accounted for by depletion of storage in the deep Starpoint aquifer system. No shallow ground-water or surface-water source is necessary to account for the inflows. Efforts to "force" surface water from Electric Lake into the mine with the model, described in HCI (2003), require unreasonably high values of hydraulic conductivity for the Diagonal Fault beneath the lake.

The 2003 Model estimates that mine inflows and pumping as of April 2003 resulted in decreased flow in Upper Huntington/Electric Lake, Fish, and Mud Creeks by about 0.2, 0.1, and

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0.3 cfs, respectively (Table 1). The total reduction in the rate of ground-water discharge to Scofield Reservoir was estimated to be about 0.4 cfs, or 200 gpm.

The 2003 Model was also used to make very limited predictive simulations. The predictive simulations suggest that by 2014, the impact on Scofield Reservoir would increase to about 2.2 cfs (1,000 gpm). The 2003 Model also predicts that the inflow rate to the Skyline mine from all sources will decrease by 2014 to approximately 3,700 gpm as a result of diminished hydraulic heads in the deep aquifer system. However, the 2003 Model did not incorporate current and future mine flooding conditions in the predictive simulations. Scenarios described in HCI (2003) yield significantly different results when the mine flooding is included, as will be seen below.

#### 3.0 2004 SIMULATIONS USING EXISTING GROUND-WATER FLOW MODEL

The 2004 simulations required no changes to the 2003 Model grid or to the hydrogeology, streams, faults, recharge, or wells. However, major changes were required in the simulation of the major mine inflows and the mine excavations, in order to simulate the effects of mine flooding.

Beginning in October 2002, ground water was allowed to flood portions of the 8-Left and 9-Left longwall panels up to seals placed at an elevation of 8,110 ft NGVD. The pool level was maintained at 8,110 ft until 7 January 2004, when pumps were shut off and the water level was allowed to rise. The pool level reached an elevation of 8,130 ft in the 8-Left, 9-Left, 11-Left and 12-Left panels (Figure 2) in about mid April, 2004. According to mine plans, the pool level will rise to an elevation of 8,290 ft before pumps are again used to maintain the level.

Preliminary simulations in 2004 showed that impacts to surface waters in predictive simulations are sensitive to current and future mine inflow rates, and these rates are highly dependent on the pressures at the individual inflow points induced by the pool of standing water. Consequently, all drain nodes representing mine workings and major inflows were modified to account for the flooding. The inflow rate of a drain node is calculated as:

$$Q = C_L \left( H_C - H_S \right) \tag{1}$$

where

Q = ground-water discharge to node (cfs),

 $H_S$  = specified elevation of node equal to pool level for the flooded portion of the mine and floor elevation for the nodes above pool level (ft),

 $H_C$  = model-calculated formation water level (ft), and

 $C_L$  = leakance factor for node (ft<sup>2</sup>/s).

Changes in the pool level were simulated using the following schedule:

<u>Date</u>	Pool Level, ft
November 2002	8,100
April 2004	8,130
August 2004	8,230
September 2004	8,250
January 2005	8,290

Figure 2 shows the locations of the pool levels in time, and is based on the elevation of the LOB coal seem. It should be noted that simulated flooding in the 11-Left and 12-Left mining area begins in April 2004 when the pool level reaches an elevation of 8,130 ft, though in reality flooding began sometime before that date. The specified head ( $H_s$ ) for each drain node within the flooded portion of the mine was changed from the original underground elevation to the elevations of the different pool levels, at the respective times described above. Leakance factors, which had been derived from calibration to measured inflows in the 2003 Model, were left unchanged. Comparisons between simulated and measured inflows and water levels are shown in Figures 14 and 15.

#### 3.1 VERIFICATION TO CURRENT DATA

DOGM (2004) requested verification of the 2003 Model results using data collected after the model calibration in April 2003. Available data includes additional water levels in 5 monitoring wells, through mid January 2004, and two additional <u>estimates</u> of total ground-water inflow to the mines. The recent monitoring-well hydrographs (see, for instance, 79-35-1a and 99-4-1, in Figure 4) show perturbations in 2003 and 2004 that HCI attributes to rising pool levels, including independently-rising pools in 9 Left and 11 Left.

Verification of the model to current data was completed by extending the simulations of mine inflows and water levels from May 2003 to April 2004 while incorporating the flooding condition since November 2002 in 10-Left area, and comparing to measured data. Figure 14 shows a comparison of the modeled and measured individual inflows; Figure 15 shows a

comparison of water levels in monitoring wells; and Figures 16-17 show the modeled and measured (estimated) total mine inflow.

## 3.2 PREDICTIVE SCENARIOS

DOGM (2004) also requested predictions of the impacts to surface water bodies other than the two reservoirs, and a prediction of the recovery time of the reservoir after mining activity ends. Because of uncertain mining and mine-dewatering plans, however, it was necessary to model two different scenarios in order to make these predictions. Scenario I assumes that the mine flooding schedule will proceed as described above, with the final pool elevation maintained at 8,290 ft until the year 2014. As described below, however, results of Scenario I suggest that the high pool elevation would decrease ground-water inflow rates so that the current pumping rate of JC-3 (3,100 gpm) could not be sustained. Consequently, Scenario II assumes that instead of maintaining the high pool elevation, the pumping rate of JC-3 would be maintained at about 3,100 gpm, and the pool allowed to reach its own level (8,130 ft according to the model results). In Scenario II, as in Scenario I, JC-1 continues to pump at a rate of 4,000 gpm through 2013. All pumps are shut down at the end of 2013, and the pool is allowed to rise to its static level.

## 3.2.1 Scenario I: Maintenance of Pool at 8,290 ft

Figure 16 shows the total mine inflow and inflows from major water hits predicted if the underground pool elevation is maintained at 8,290 ft; the simulated ground-water budget at end of mining is shown in Table 2. The model predicts that the increased pressure on the mine inflows (the decreased differential between formation head and pressure at inflow point) would reduce the flow rates to the extent that pumping-well JC-3 would have to be shut down in order for the pool to reach 8,290 ft.

## 3.2.2 Scenario II: Maintainence of JC-3 Pumping Rate through 2013

Figure 17 shows the predicted total mine inflow and inflow from major water hits if the pool level is not maintained, but JC-3 continues to pump at about 3,100 gpm. The simulated ground-water budget at end of mining is shown in Table 3. The model predicts that by maintaining the pool level at an elevation of approximately 8,130 ft through the end of year 2013, the resultant inflow volume will be sufficient to allow JC-3 to be pumped at a rate of about 4,000 gpm in 2005, reducing to about 2,000 gpm by 2013.

#### 3.3 SIMULATED IMPACT TO STREAMS DUE TO MINING

The impact to streams was simulated as the difference between ground-water discharge to the streams under pre-mining conditions and ground-water discharge during mining (or post-mining) conditions. As shown below, the maximum value of the impact will depend on the elevation at which the underground pool will be maintained. Figure 18 shows predicted impacts to Fish Creek, Mud Creek, and Huntington Creek (total, including the Electric Lake and Left Fork). Separate impacts to Huntington Creek (above and below Electric Lake), Electric Lake, and Left Fork can be seen in Tables 1-3.

## Scenario I

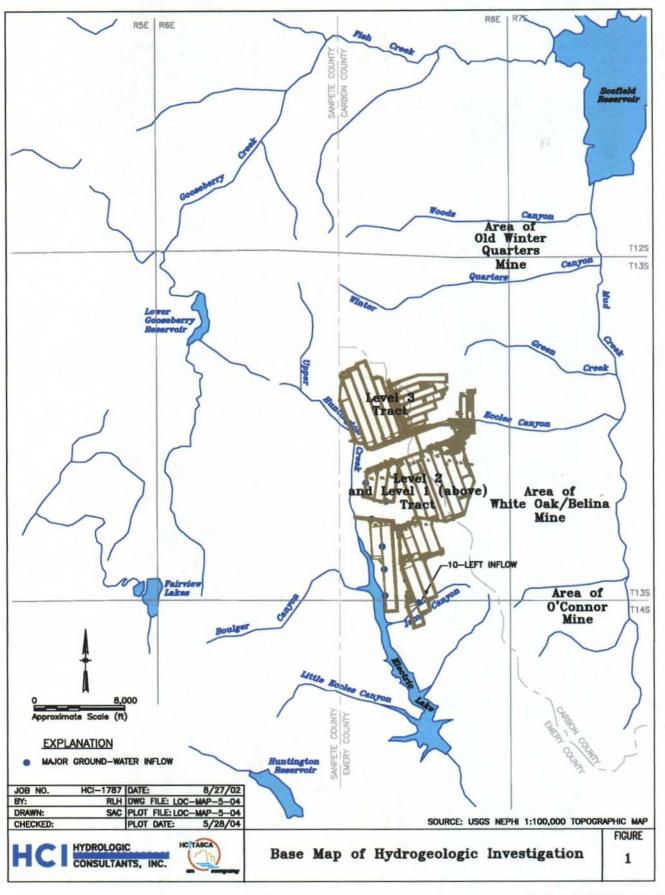
In the first scenario, with the pool elevation maintained at 8,290 ft, and inflow rates greatly reduced after 2005, the impacts to Fish Creek, Mud Creek, and Huntington Creek will reach maximum values of 0.3 cfs, 1.5 cfs, and 1.4 cfs, respectively. The maxima will occur at 3 to 10 years after mine dewatering is completed (Figure 18). Recovery of the hydrologic system will take a very long period of time because of the very low vertical hydraulic conductivity of overburden and interburden layers ( $K_v$ =0.0001 ft/day). The model predicts that the impacts to the Creeks after about 50 years of recovery will be 0.15 cfs, 0.4 cfs, and 0.7 cfs, respectively.

## Scenario II

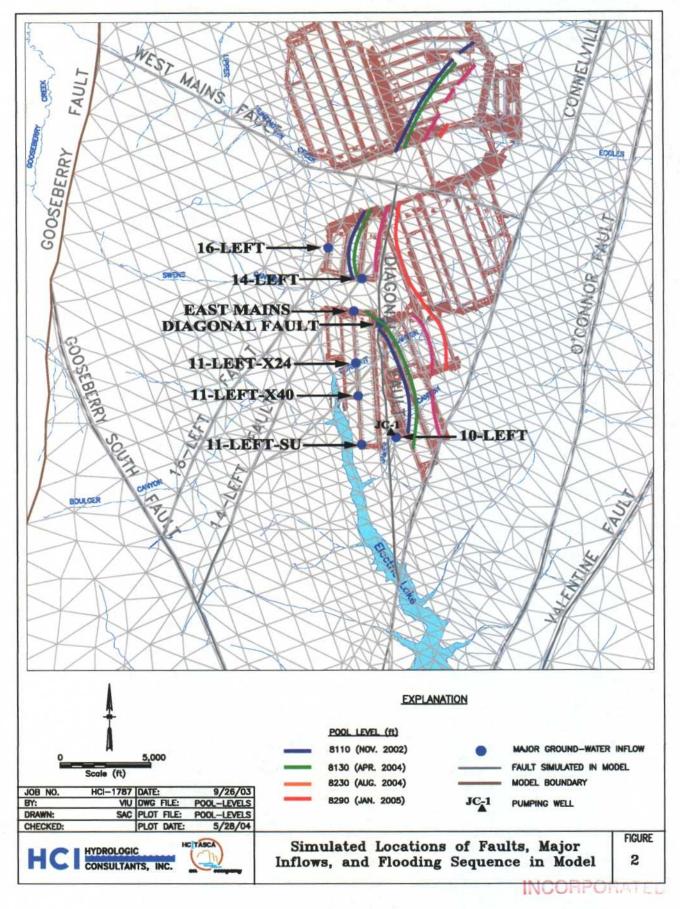
The second scenario, with the pool elevation "maintained" at 8,130 ft, results in predicted maximum values of 0.4 cfs, 1.8 cfs, and 1.7 cfs for Fish Creek, Mud Creek, and Huntington Creek, respectively. The maximum values will occur at from 4 to 11 years after the end of mine dewatering (Figure 18). Again recovery will take a very long period of time because of the very low vertical hydraulic conductivity of the overburden and interburden layers. The model predicts that impacts to Fish Creek, Mud Creek, and Huntington Creek after about 50 years of recovery will be 0.15 cfs, 0.4 cfs, and 0.7 cfs, respectively.

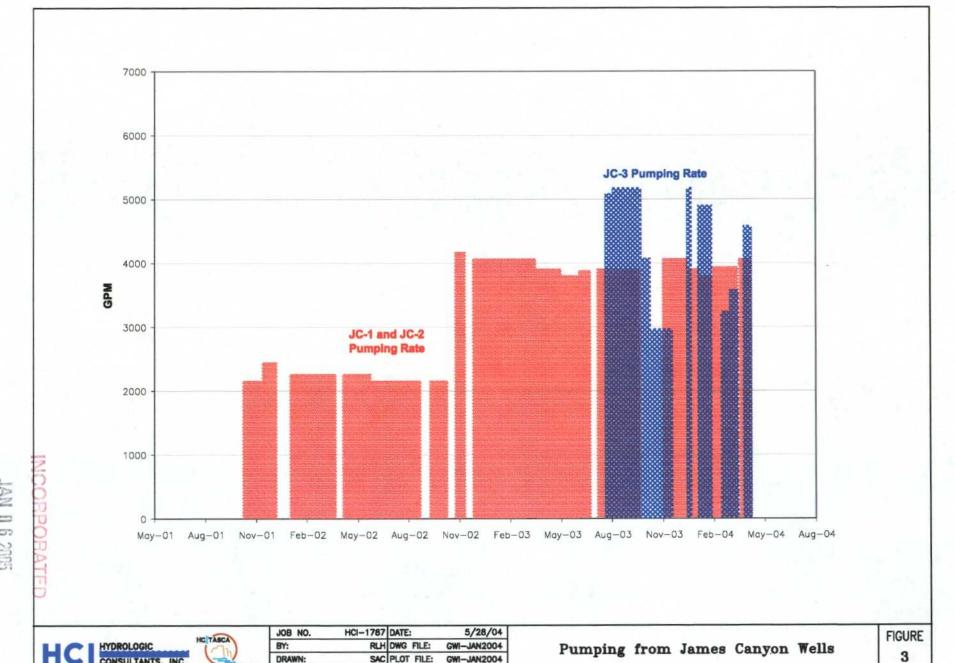
## 4.0 REFERENCES

- Hydrologic Consultants, Inc., 2002, Progress Report No. 2, Updated conceptual hydrogeology, evaluation of current and future dewatering, and proposed testing program for Skyline Mine: report submitted to Canyon Fuel Company, February.
- Hydrologic Consultants Inc., 2003, Findings of ground-water flow modeling of Skyline Mine and surrounding area, Carbon, Sanpete, and Emery Counties, Utah: report prepared for Manning, Curtis, Bradshaw & Bednar LLC, September.
- Utah Division of Oil, Gas, and Mining, 2004, Findings for HCI ground-water model report in PHC, Canyon Fuel Company, LLC, Skyline Mine, C/007/0005 #1871: Letter to Dan Meadors, April 23.



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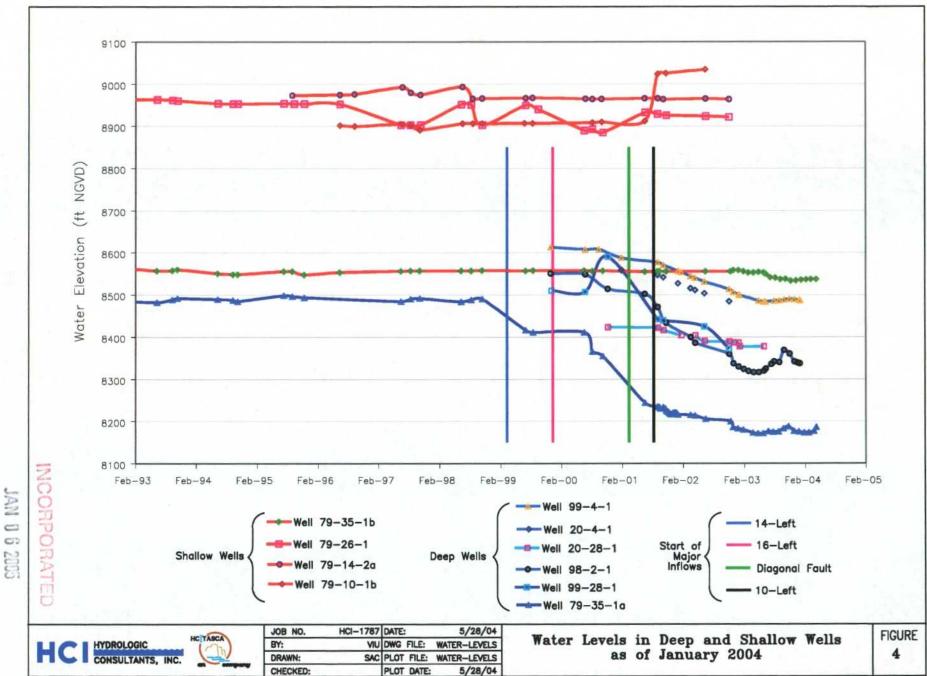
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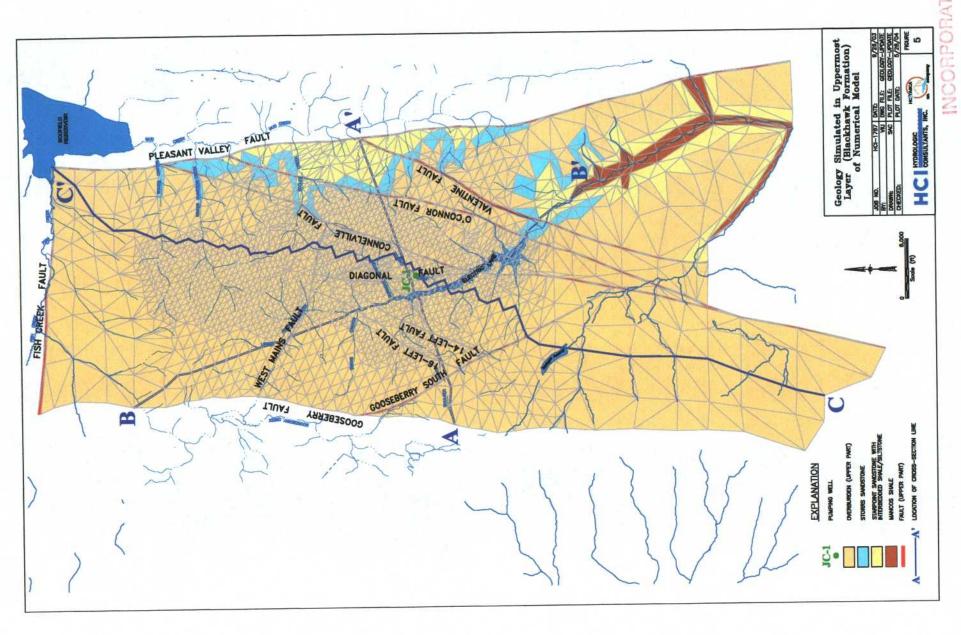
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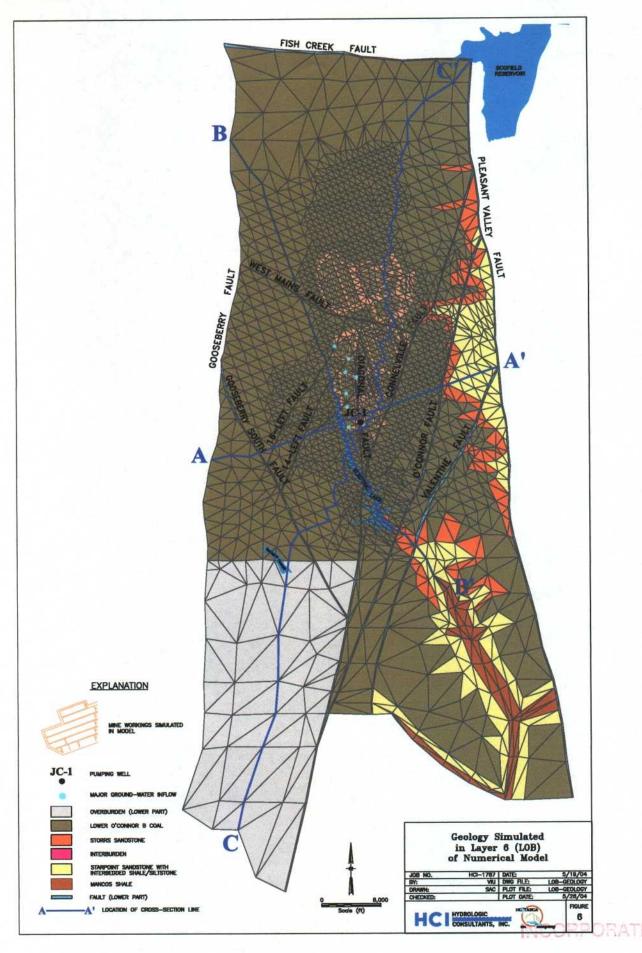
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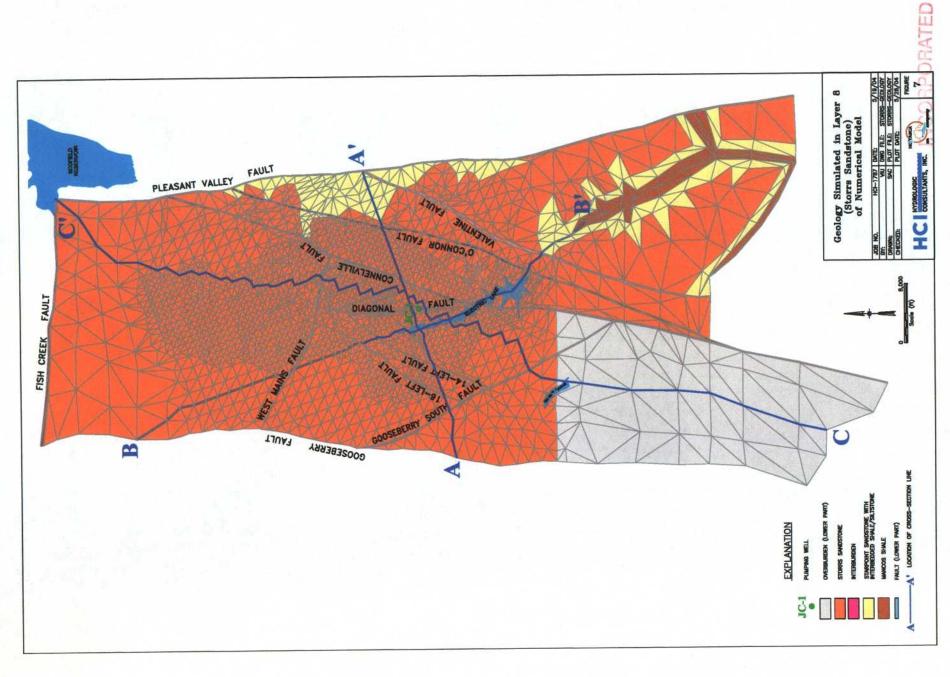
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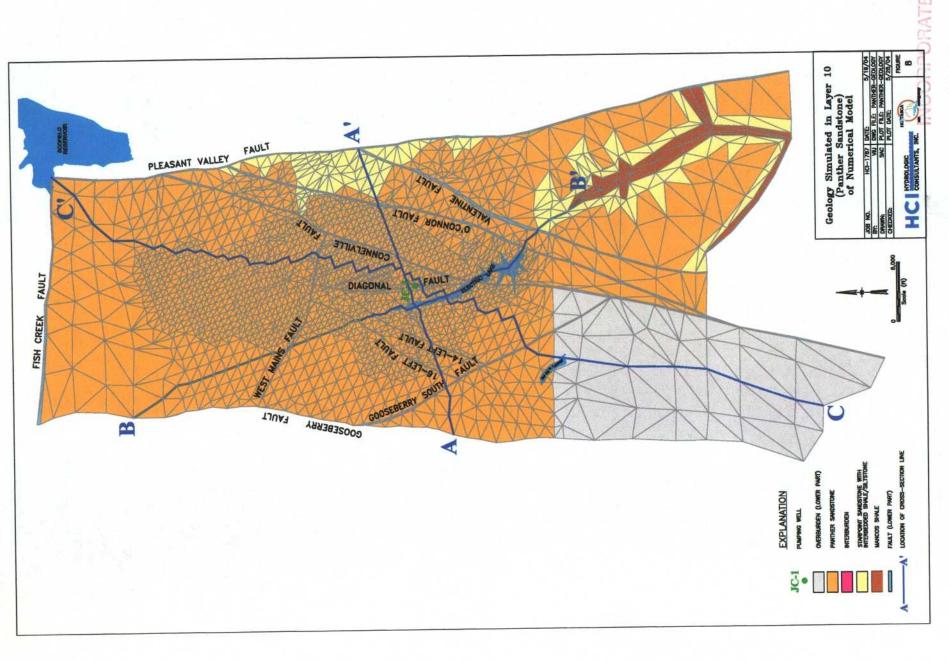
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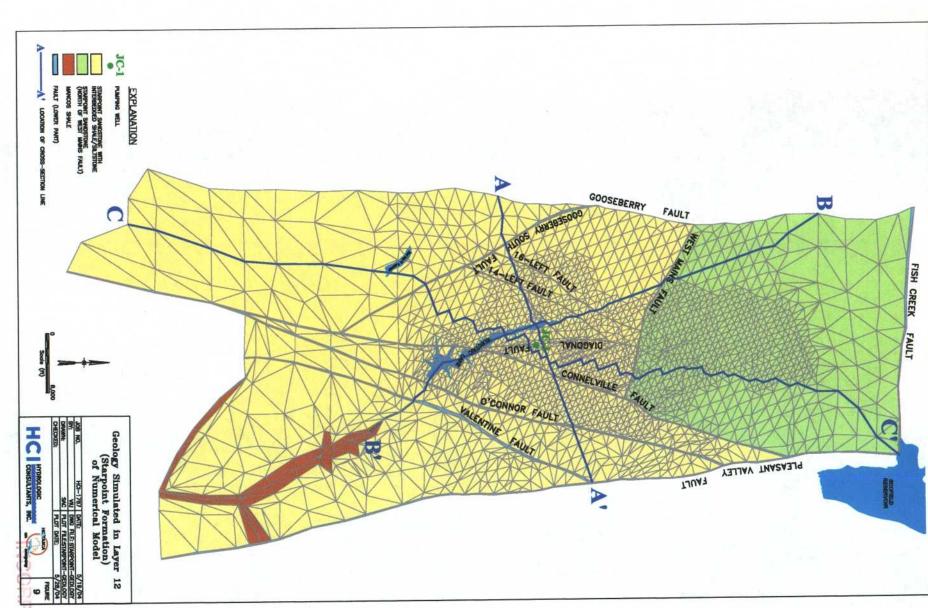


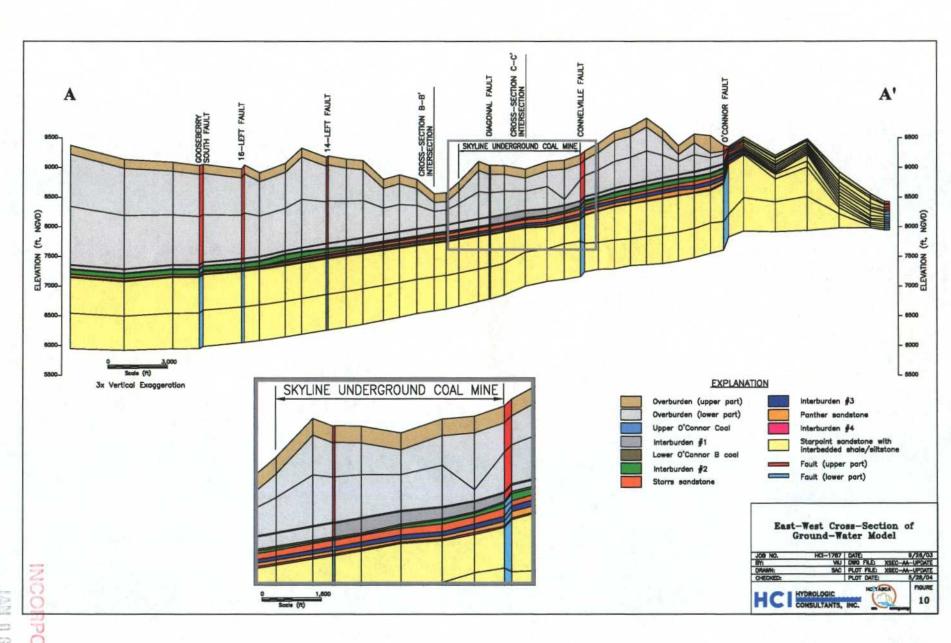


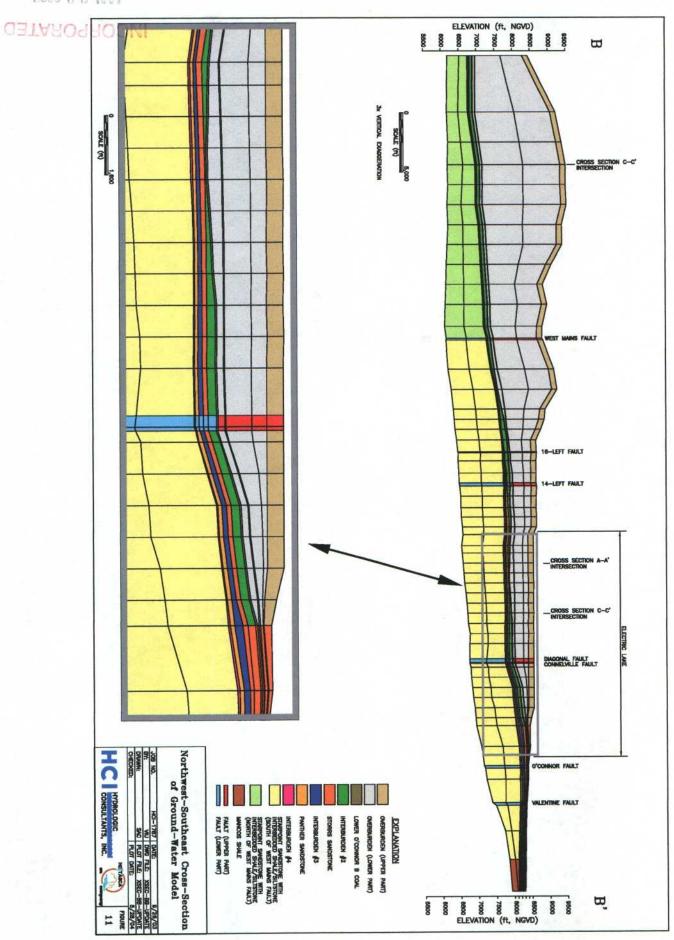


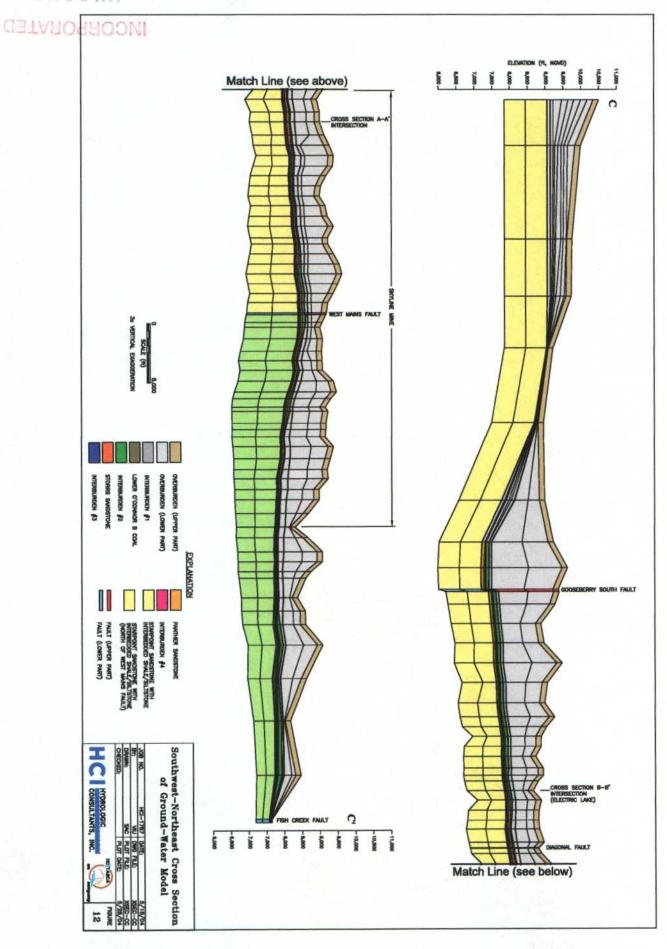


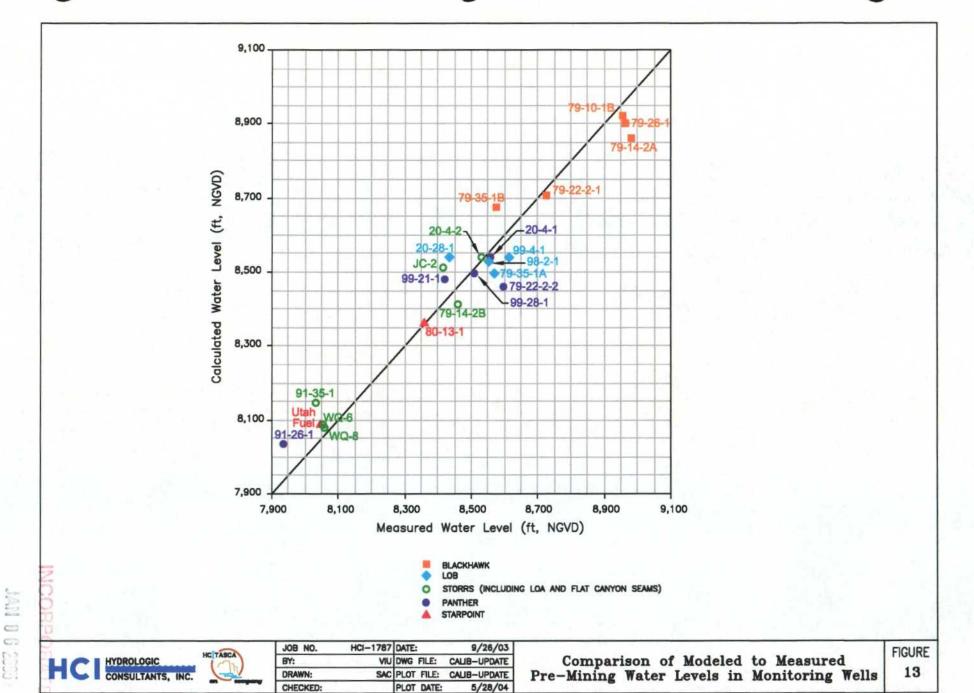


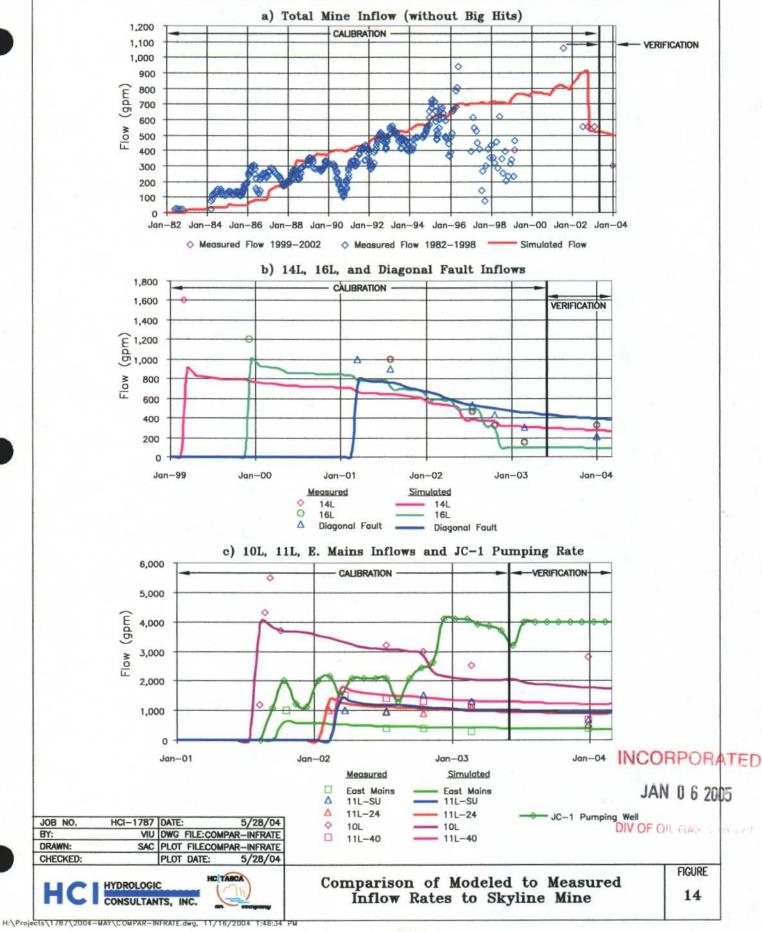


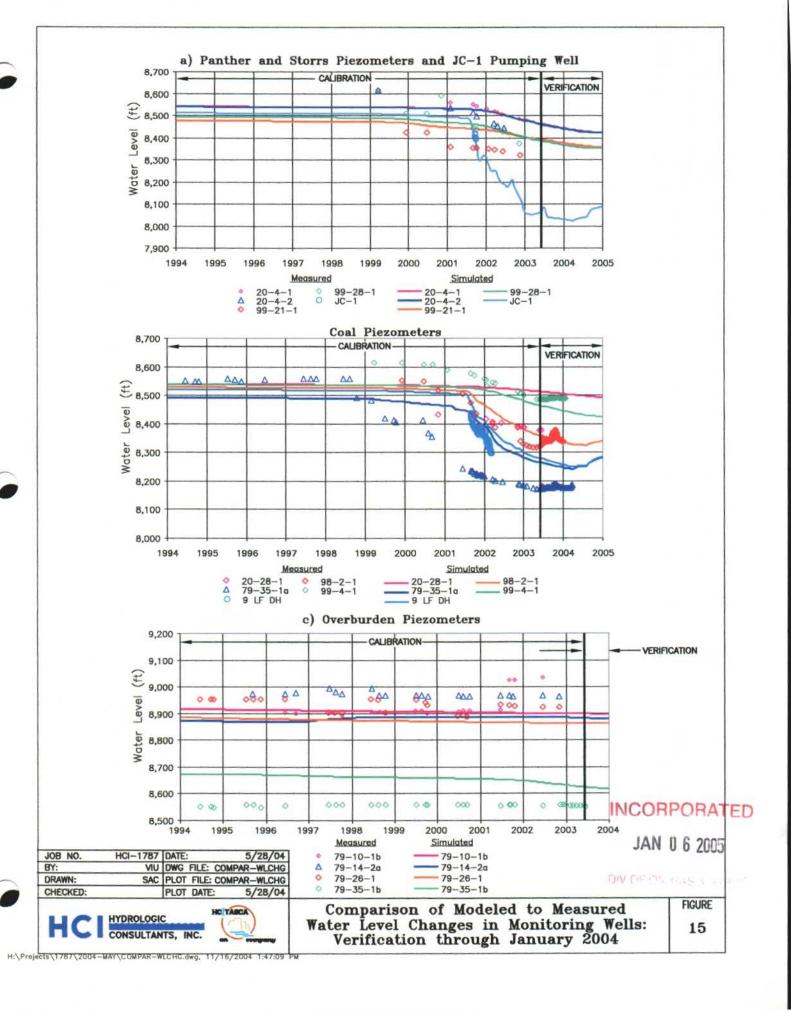


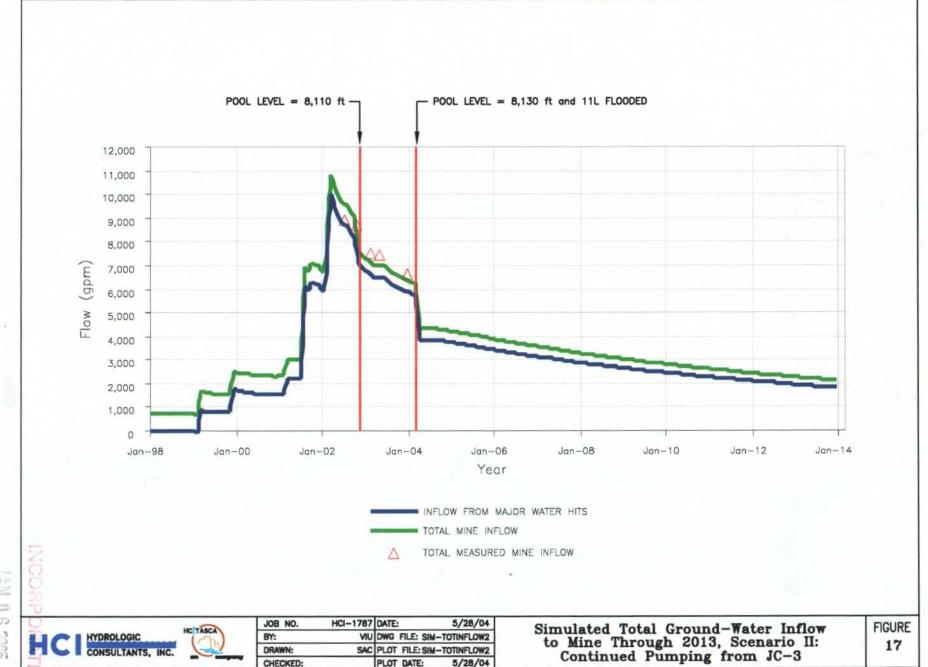








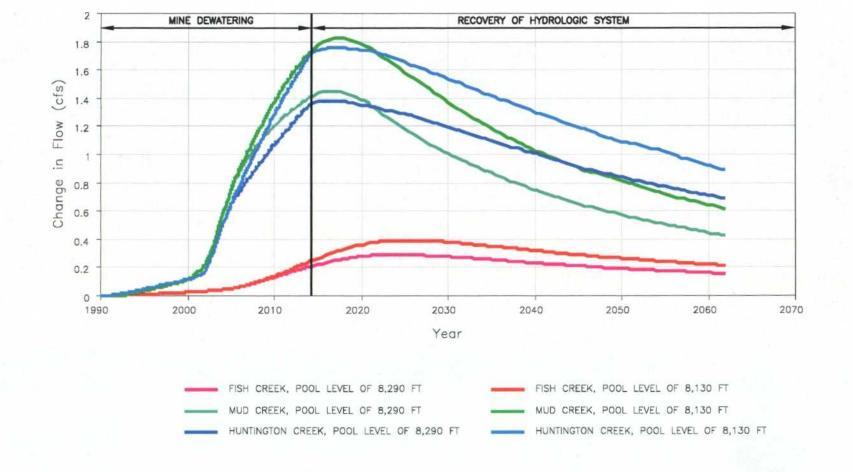




CHECKED:

PLOT DATE:

5/28/04



HCI HYDROLOGIC CONSULTANTS, INC.



JOB NO.	HCI-1787	DATE:	5/28/04
BY:	VIU	DWG FILE:	PRED-IMPACT
DRAWN:	SAC	PLOT FILE:	PRED-IMPACT
CHECKED:		PLOT DATE:	5/28/04

Predicted Impact to Major Streams in Model Domain (VIU new results)

FIGURE 18

TABLE 1
Simulated Ground-Water Budgets for Pre-Mining, Current Mining, and End of Mining Conditions Without Flooding Mine

			ding Mine		
			ing Conditions		
Inflow Component		w (cfs)	Outflow component	(	cfs)
Recharge from Precipitation	5	4.6	GW Boundary Outflow		0
GW Boundary Inflow		0 GW Discharge to SW			
echarge to GW from Electric Lake 0.1			a) Mud Creek	12.4	
GW Storage 0			b) Fish Creek	6.9	
			c) Upper Huntington Creek and Other Creeks to Electric Lake		9.4
			d) Electric Lake		1.2
			e) Huntington Creek Below Electric Lake		9.5
			f) Left Fork of Huntington Creek	15.3	
Total	5	54.7	Total	4	54.7
C	urrent l	Mining Co	onditions (April 30, 2003)		
Inflow Component	Flow (cfs)	Change (cfs)	Outflow component	Flow (cfs)	Chang (cfs)
Pacharge from Precipitation	54.6	0	GW Boundary Outflow	0	0
Recharge from Precipitation GW Boundary Inflow	0	0	GW Discharge to SW	U	U
Recharge to GW from Electric Lake	0.2	0.1	a) Mud Creek	12.1	-0.3
GW Storage	25.1	25.1	b) Fish Creek	6.8	-0.3
3 w Storage	23.1	23.1	c) Upper Huntington Creek and Other	0.0	-0.1
			Creeks to Electric Lake	9.4	0
			d) Electric Lake	1.1	-0.1
			e) Huntington Creek Below Electric Lake	9.4	-0.1
			f) Left Fork of Huntington Creek	15.3	0
			Subtotal	54.1	-0.6
			Pumping from JC-1	8.6	8.6
		N. M. Salah	Mine Inflow	17.2	17.2
Total	79.9	25.2	Total	79.9	25.2
Calculated impact to Electric Lake = GW discharge to Upper Huntington (			e to GW from Electric Lake + change in Lake 0.1+0.1=0.2		0.2
Enc	of Min	ning Cond	itions (December 31, 2013)		
Inflow Component	Flow (cfs)	Change (cfs)	Outflow component	Flow (cfs)	Chang (cfs)
Recharge from Precipitation	54.6	0	GW Boundary Outflow	0	0
GW Boundary Inflow	0	0	GW Discharge to SW	U	U
Recharge to GW from Electric Lake	0.6	0.5	a) Mud Creek	10.6	-1.8
GW Storage	12.6	12.6	b) Fish Creek	6.6	-0.3
OW Storage	12.0	12.0	c) Upper Huntington Creek and Other	9.2	-0.2
			Creeks to Electric Lake d) Electric Lake	0.0	0.2
				0.9	-0.3
			e) Huntington Creek Below Electric Lake f) Left Fork of Huntington Creek	9.0	-0.5
			Subtotal	14.8	-0.5
				51.1	-3.6
			Pumping from JC-1 Mine Inflow	8.4	8.4
Table	67.0	12.1		-	8.2
Total	67.8	13.1	Total	67.7	13.0
Calculated impact to Electric Lake = GW discharge to Upper Huntington (			to GW from Electric Lake + change in		1.0

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TABLE 2
Simulated Ground-Water Budgets for Pre-Mining, Current Mining, and End of Mining Conditions With Floding Mine to Pool Level of 8,290 ft

		Pre-Mini	ng Conditions			
Inflow Component	Flo	w (cfs)	Outflow component	(	cfs)	
Recharge from Precipitation		64.6	GW Boundary Outflow	0		
GW Boundary Inflow		0	GW Discharge to SW			
Recharge to GW from Electric Lake			a) Mud Creek	12.4		
GW Storage	0		b) Fish Creek	6.9		
			c) Upper Huntington Creek and Other		9.4	
			Creeks to Electric Lake			
			d) Electric Lake		1.2	
			e) Huntington Creek Below Electric Lake		9.5	
			f) Left Fork of Huntington Creek Total		15.3	
Total	5	54.7			54.7	
Cı	irrent N	Ining Co	nditions (April 30, 2003)			
	Flow	Change	0.15	Flow	Change	
Inflow Component	(cfs)	(cfs)	Outflow component	(cfs)	(cfs)	
Recharge from Precipitation	54.6	0	GW Boundary Outflow	0	0	
GW Boundary Inflow	0	0	GW Discharge to SW			
Recharge to GW from Electric Lake	0.2	0.1	a) Mud Creek	12.1	-0.3	
GW Storage	23.6	23.6	b) Fish Creek	6.8	-0.1	
White the second second	Herota vij		c) Upper Huntington Creek and Other	9.4	0	
			Creeks to Electric Lake	9.4	U	
			d) Electric Lake	1.1	-0.1	
			e) Huntington Creek Below Electric Lake	9.4	-0.1	
			f) Left Fork of Huntington Creek	15.3	0	
			Subtotal	54.1	-0.6	
			Pumping from JC-1	8.6	8.6	
			Mine Inflow	15.7	15.7	
Total	78.4	23.7	Total	78.4	23.7	
Calculated impact to Electric Lake = GW discharge to Upper Huntington C			to GW from Electric Lake + change in		0.2	
EBO			itions (December 31, 2013)	Flow	Chang	
Inflow Component	Flow (cfs)	Change (cfs)	Outflow component	(cfs)	(cfs)	
Recharge from Precipitation	54.6	0	GW Boundary Outflow	0	0	
GW Boundary Inflow	0	0	GW Discharge to SW			
Recharge to GW from Electric Lake	0.4	0.3	a) Mud Creek	11.0	-1.4	
GW Storage	6.3	6.3	b) Fish Creek	6.7	-0.2	
	THE REAL PROPERTY.		c) Upper Huntington Creek and Other	0.2	0.2	
			Creeks to Electric Lake	9.2	-0.2	
			d) Electric Lake	1.1	-0.1	
			e) Huntington Creek Below Electric Lake	9.2	-0.3	
			f) Left Fork of Huntington Creek	14.9	-0.4	
			Subtotal	52.1	-2.6	
			Pumping from JC-1	8.9	8.9	
			Mine Inflow	0.3	0.3	
	(10	111	Total	61.3	6.6	
Total	61.3	6.6	Total	01.5	0.0	

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TABLE 3
Simulated Ground-Water Budgets for Pre-Mining, Current Mining, and End of Mining Conditions With Floding Mine to Pool Level of 8,130 ft

		Pre-Mini	ng Conditions		
Inflow Component	Flo	w (cfs)	Outflow component		(cfs)
echarge from Precipitation		54.6	GW Boundary Outflow		0
W Boundary Inflow		0	GW Discharge to SW		
echarge to GW from Electric Lake		0.1	a) Mud Creek		12.4
W Storage		0	b) Fish Creek		6.9
			c) Upper Huntington Creek and Other		9.4
			Creeks to Electric Lake		
			d) Electric Lake		1.2
			e) Huntington Creek Below Electric Lake		9.5
			f) Left Fork of Huntington Creek		15.3
Total	1	54.7	Total		54.7
C	urrent N	Ining Co	nditions (April 30, 2003)		
	Flow	Change	0.49	Flow	Change
Inflow Component	(cfs)	(cfs)	Outflow component	(cfs)	(cfs)
echarge from Precipitation	54.6	0	GW Boundary Outflow	0	0
W Boundary Inflow	0	0	GW Discharge to SW		
echarge to GW from Electric Lake	0.2	0.1	a) Mud Creek	12.1	-0.3
W Storage	23.6	23.6	b) Fish Creek	6.8	-0.1
			c) Upper Huntington Creek and Other	0.4	0
			Creeks to Electric Lake	9.4	0
			d) Electric Lake	1.1	-0.1
			e) Huntington Creek Below Electric Lake	9.4	-0.1
			f) Left Fork of Huntington Creek	15.3	0
			Subtotal	54.1	-0.6
			Pumping from JC-1	8.6	8.6
			Mine Inflow	15.7	15.7
Total	78.4	23.7	Total	78.4	23.7
alculated impact to Electric Lake =	change in	recharge	to GW from Electric Lake + change in		0.0
W discharge to Upper Huntington (	creek and	Electric I	ake 0.1 + 0.1 = 0.2		0.2
Enc	d of Min	ing Condi	tions (December 31, 2013)		
THE RESERVE TO SERVE THE RESERVE TO SERVE THE RESERVE TO SERVE THE RESERVE TO SERVE THE RESERVE TO SERVE THE RESERVE TO SERVE THE RESERVE TO SERVE THE RESERVE TO SERVE THE RESERVE TO SERVE THE RESERVE TO SERVE THE RESERVE TO SERVE THE RESERVE TO SERVE THE RESERVE TO SERVE THE RESERVE TO SERVE THE RESERVE	Flow	Change		Flow	Change
Inflow Component	(cfs)	(cfs)	Outflow component	(cfs)	(cfs)
echarge from Precipitation	54.6	0	GW Boundary Outflow	0	0
W Boundary Inflow	0	0	GW Discharge to SW		
the state of the s	0.5	0.4	a) Mud Creek	10.7	-1.7
charge to GW from Electric Lake					-0.2
		10.0	b) Fish Creek	6.7	
	10.0	10.0	b) Fish Creek c) Upper Huntington Creek and Other	6.7	
		10.0	c) Upper Huntington Creek and Other	9.2	-0.2
		10.0	c) Upper Huntington Creek and Other Creeks to Electric Lake	9.2	
		10.0	c) Upper Huntington Creek and Other Creeks to Electric Lake d) Electric Lake	9.2	-0.3
		10.0	c) Upper Huntington Creek and Other Creeks to Electric Lake d) Electric Lake e) Huntington Creek Below Electric Lake	9.2 0.9 9.1	-0.3 -0.4
		10.0	c) Upper Huntington Creek and Other Creeks to Electric Lake d) Electric Lake	9.2 0.9 9.1 14.9	-0.3 -0.4 -0.4
		10.0	c) Upper Huntington Creek and Other Creeks to Electric Lake d) Electric Lake e) Huntington Creek Below Electric Lake f) Left Fork of Huntington Creek Subtotal	9.2 0.9 9.1	-0.3 -0.4
		10.0	c) Upper Huntington Creek and Other Creeks to Electric Lake d) Electric Lake e) Huntington Creek Below Electric Lake f) Left Fork of Huntington Creek	9.2 0.9 9.1 14.9 51.5	-0.3 -0.4 -0.4 -3.2
		10.0	c) Upper Huntington Creek and Other Creeks to Electric Lake d) Electric Lake e) Huntington Creek Below Electric Lake f) Left Fork of Huntington Creek Subtotal Pumping from JC-1	9.2 0.9 9.1 14.9 51.5 8.9 4.7	-0.3 -0.4 -0.4 -3.2 8.9 4.7
	65.1	10.4	c) Upper Huntington Creek and Other Creeks to Electric Lake d) Electric Lake e) Huntington Creek Below Electric Lake f) Left Fork of Huntington Creek Subtotal Pumping from JC-1 Mine Inflow Total	9.2 0.9 9.1 14.9 51.5 8.9 4.7 65.1	-0.3 -0.4 -0.4 -3.2 8.9 4.7
W Storage  Total	65.1 change in	10.4 n recharge	c) Upper Huntington Creek and Other Creeks to Electric Lake d) Electric Lake e) Huntington Creek Below Electric Lake f) Left Fork of Huntington Creek Subtotal Pumping from JC-1 Mine Inflow  Total to GW from Electric Lake + change in	9.2 0.9 9.1 14.9 51.5 8.9 4.7 65.1	-0.3 -0.4 -0.4 -3.2 8.9 4.7

# HCI Technical Memorandum November 11, 2004

# Numerical Simulation of post Mining Conditions Skyline Mine

# Attachment to:

HCI Supplemental Report
Ground-water Flow Modeling of Skyline Mine and Surrounding Area,
Carbon, Sanpete, and Emery Counties, Utah

June 2004

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Hydrologic Consultants, Inc. of Colorado 143 Union Blvd., Ste. 525 Lakewood, Colorado 80228 USA telephone: 303-969-8033 fax: 303-969-8357 e-mail: hcico@hcico.com http://www.hcitasca.com

## TECHNICAL MEMORANDUM

TO: Chris Hansen, Canyon Fuel Company LLC

HCI-1787

FROM:

Roger Howell, HCI

Vladimir Ugorets, HCI

DATE:

November 11, 2004

SUBJECT: Numerical Simulation of Post Mining Conditions, Skyline Mine

Comments received from the Utah Department of Geology and Mining (Galecki, 2004) regarding the most recent modelling of mine inflows at Skyline Mine (HCI, 2004) included a request to investigate the maximum pool elevation and possible impacts to surface streams from residual drawdown of the ground-water system after all mining ceases. This memorandum describes the results of steady-state simulations using the ground-water flow model described in HCI (2003 and 2004) to predict:

- a) The maximum elevation of the pool level in underground mine workings,
- b) Changes in ground-water levels compared to pre-mining conditions, and
- Possible residual impacts to the surface-flow in Huntington Creek, Mud Creek, and Fish Creek basins.

#### SIMULATION OF POST-MINING CONDITIONS

A simulation of the post-mining water levels was completed by:

- 1) turning off the drain nodes representing the mine discharge,
- 2) turning off pumping node representing JC-1 pumping well, and
- 3) replacing mined-out elements with the hydraulic conductivity of coal (1 ft/day) by elements with very high hydraulic conductivity (10<sup>6</sup> ft/day) to simulate the voids being flooded.

The modeling was done in steady-state only, and therefore predicts the ultimate level that will be reached by the underground pool, but not the time required to reach the ultimate level. It should be noted that all 3 mining areas (Level 1, 2, and 3 Tract) are assumed connected laterally and vertically so that a single pool forms. All other hydraulic parameters and boundary conditions remain the same as in HCI (2003), including elements with the enhanced hydraulic conductivity that had been used in previous model simulations to represent subsidence and fracturing (gob) above mining workings.

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### RESULTS OF SIMULATION

Results of the post-mining simulation indicate that some time after all pumping from the mine and pumping from JC-1 are stopped:

- a) The pool level within the underground mine workings will attain an elevation of about 8,475 ft, or 102 ft below the Eccles Canyon portal; the location of the post-mining steadystate beachline within Level 2 and Level 3 Tracts is shown in Figure 1,
- b) Post-mining ground-water levels within the Level 1, 2, and 3 Tracts will differ from premining conditions as a result of flooding of the mine workings and increased hydraulic conductivity within the GOB layer; general changes will include:

Level 1 Tract – ground-water levels lowered by 20 to 160 ft, Level 2 Tract – ground-water levels lowered by 10 to 60 ft, Level 3 Tract – ground-water levels raised by 20 to 160 ft.

c) The interconnected mine workings will act as a large "short circuit" of the natural ground-water flow path, resulting in long-term changes in the rates of ground-water discharge to the major surface water bodies; details (shown in Table 1)include:

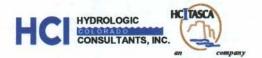
Upper Huntington Creek plus Electric Lake – essentially unchanged, Huntington Creek Below Electric Lake – discharge decreased by 0.2 cfs (-90 gpm), Mud Creek Basin – discharge increased by 0.2 cfs (+90 gpm), and Fish Creek Basin – essentially unchanged.

## DISCUSSION

The ultimate pool elevation in Levels 2 and 3 is strongly affected by connection with the upper workings in Level 1. The pool elevation could be significantly lowered by closing off the connection between the upper and lower workings.

Much of the impacts to surface streams predicted by the model result from the increased vertical hydraulic conductivity modeled in the gob layer above mined-out coals. A more exacting study of the impacts might take into account a gradual healing of the fractures within this gob zone over time.

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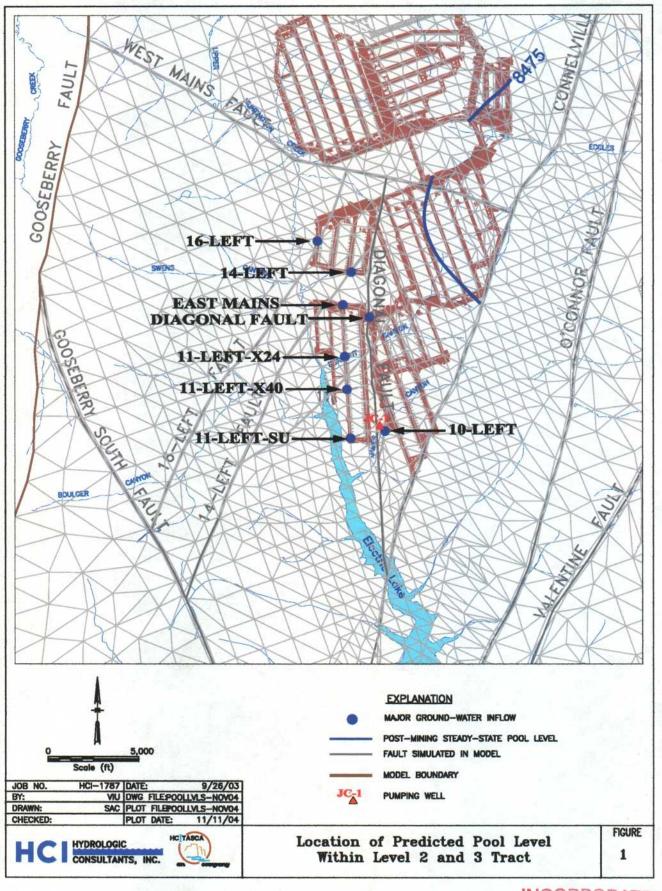


#### REFERENCES

- Galecki, Greg, 2004, Preliminary Appendix-K questions (HCI-2004): e-mail correspondence to Chris Hansen, Skyline Mine, September 1.
- Hydrogeologic Consultants, Inc., 2003, Findings of ground-water flow modeling of Skyline Mine and surrounding area, Carbon, Sanpete, and Emery Counties, Utah: report prepared for Manning, Curtis, Bradshaw & Bednar LLC, September
- Hydrogeologic Consultants, Inc., 2004, Ground-water flow modeling of Skyline Mine and surrounding are, Carbon, Sanpete, and Emery Counties, Utah: supplemental report prepared for Manning, Curtis, Bradshaw & Bednar LLC, June

Attachments: Figure 1 - Location of predicted pool level within Level 2 and 3 Tract.

Table 1 – Simulated ground-water budget for pre-mining and post-mining conditions.



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TABLE 1
Simulated Ground-Water Budgets for Pre-Mining and Post-Mining Conditions

	Pre-Minii	ng Conditions		
Inflow	(cfs)	Outflow	(cfs)	
Recharge from Precipitation	54.6	GW Boundary Outflow	0	
GW Boundary Inflow	0	GW Discharge to SW	Call H	
Recharge to GW from Electric Lake	0.1	a) Mud Creek	12.4	
GW Storage	0	b) Fish Creek	6.9	
		c) Upper Huntington Creek	9.4	
		d) Electric Lake	1.2	
		e) Huntington Creek below Electric Lake	9.5	
		f) Left Fork	15.3	
Total	54.7	Total	54.7	
	Post-Mini	ng Conditions		
Inflow	(cfs)	Outfow	(cfs)	Change
Recharge from Precipitation	54.6	GW Boundary Outflow	- 0	The other last
GW Boundary Inflow	0	GW Discharge to SW		
Recharge to GW from Electric Lake	0.1	a) Mud Creek	12.6	0.2
GW Storage	0.0	b) Fish Creek	6.9	0.0
		c) Upper Huntington Creek	9.5	0.1
		d) Electric Lake	1.1	-0.1
		e) Huntington Creek below Electric Lake	9.4	-0.1
		f) Left Fork	15.2	-0.1
Total	54.7	Total	54.7	0.0